Photo: Nathalie Behring

Chapter 12

Implications of climate change for contributions by fisheries and aquaculture to Pacific Island economies and communities

Johann D Bell, Chris Reid, Michael J Batty, Edward H Allison, Patrick Lehodey, Len Rodwell, Timothy D Pickering, Robert Gillett, Johanna E Johnson, Alistair J Hobday and Andreas Demmke

'Climate change impacts could change resource access 'winners' and 'losers', at both the community and national level.' (FAO 2008)[i]

i FAO (2008) *Climate Change, Energy and Food*. High-level Conference on Food Security: Challenges of Climate Change and Bioenergy, 3–5 June 2008, Food and Agriculture Organization of the United Nations, Rome, Italy.

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12.1 Introduction

Throughout Pacific Island countries and territories (PICTs) there is broad recognition that fisheries and aquaculture make vital contributions to economic development, government revenue, food security and livelihoods[1–5] (Chapters 8–11). Indeed, the Pacific Plan[6] recognises that development of the region is linked to the effective management of fish, and the habitats that support them – *'development and implementation of national and regional conservation and management measures for the sustainable use of fisheries resources'* is a priority of the Plan. The Pacific Island Forum Leaders' Vava'u Declaration[ii] reinforces the need for responsible and effective stewardship of the region's fisheries resources. The objectives and strategies of fisheries agencies throughout the region also repeat the desire to use fish for the benefit of people within the context of sustainable development.

'The Future of Pacific Islands Fisheries' study[7] now provides a roadmap for harnessing the potential economic and social benefits of fisheries and aquaculture in the face of the many drivers influencing the sector. These drivers include population growth, urbanisation, globalisation of markets, international trade policies, the world food crisis and economic constraints.

It is also clear that the plans to optimise the benefits of fisheries and aquaculture for the region are likely to be affected by climate change (Chapters 2–11). Here, we assess the vulnerability of economic development, government revenue, food supplies and livelihoods derived from fisheries and aquaculture to climate change, and the implications for PICTs.

We begin by summarising the recent contributions of oceanic, coastal and freshwater fisheries, and aquaculture, to the region. We then explain the plans PICTs have to optimise these benefits and conclude by assessing the vulnerability of these plans to the main projected changes in production of fisheries resources and aquaculture due to climate change for 2035 and 2100 under a low (B1) and high (A2) emissions scenarios (Chapters 8–11).

To provide assessments for the medium term, we have used the projections for B1 in 2100 as a surrogate for A2 in 2050 (Chapter 1). In assessing the vulnerability of economic development and government revenue, we have focused mainly on the projected changes to skipjack tuna because this species dominates the catches of industrial fleets[8] (Chapter 8). For food security, we concentrate on the projected changes to coastal fisheries because they currently provide most of the fish eaten by people in Pacific communities[3] (Chapter 9). The projected effects of climate change on all fisheries resources and aquaculture (Chapters 8–11) have been considered in assessing the vulnerability of livelihoods.

ii www.forumsec.org.fj/pages.cfm/documents/forum-resolutions

12.2 Contributions to economic development and government revenue

12.2.1 Contributions from industrial tuna fishing

The tuna industry in the Western and Central Pacific Ocean (WCPO) is based on the four species of tuna described in Chapter 8 (skipjack, yellowfin, bigeye and albacore) and is characterised by large vessels owned by major fishing companies from distant water fishing nations (DWFNs) and from PICTs. Much of the catch is marketed by multinational fish trading corporations.

The amount of tuna caught in the WCPO has doubled over the past 20 years, from 1.2 million tonnes in 1988 to ~ 2.5 million tonnes in 2009. This growth is due mainly to an increase in the catches of skipjack tuna[8]. Although the fishery has always been dominated by fleets from DWFNs, the percentage of the total catch taken by domestic and locally-based vessels has increased substantially in the last couple of decades (**Figure 12.1**). In 2009, the total landed value of catches of the four main species of tuna from the WCPO was estimated at ~ USD 4.2 billion. Of this, 395,000 tonnes, worth USD 593 million (14.2%), were caught by fishing fleets from PICTs. In 2007, the volume of fish processed within PICTs was 300,000 tonnes, representing 12.5% of the catch from the WCPO.

The total catch of tuna in the WCPO comes from two separate fisheries (1) a surface fishery targeting schools of skipjack and juvenile yellowfin tuna using purse-seine and pole-and-line fishing methods to supply canneries in the Pacific, Asia and Europe; and (2) a longline fishery, which targets mature bigeye and yellowfin tuna for the Japanese sashimi trade and other high-value markets, and albacore for canning in American Samoa and Fiji. Much of the fishing occurs within the exclusive economic zones (EEZs) of PICTs, but also on the high seas (international waters) (Chapter 1).

The catches made by the surface fishery in the WCPO are around 10 times greater than those made by the longline fishery[8]. This trend has also occurred for catches within the EEZs of several PICTs in Melanesia and Micronesia (**Figure 12.2**), because these countries are located in the tropical waters preferred by the abundant skipjack tuna. Total catches by both fisheries in Melanesia and Micronesia are an order of magnitude higher than those in the cooler waters of Polynesia, where a greater percentage of the fish are caught by longlining (**Figure 12.2**).

12.2.1.1 Surface tuna fishery

Volume and value

Catches made by the surface fishery in the WCPO are based heavily on purse-seining – more than 85% of the catch is now landed by this fishing method. Skipjack tuna make up ~ 75% of the purse-seine catch and > 90% of the pole-and-line catch. Yellowfin tuna is the other important component of the purse-seine fishery, making up ~ 20% of the catch. Relatively small quantities of bigeye tuna are caught in the surface fishery, although catches have been increasing in recent years due to the widespread use of drifting fish aggregating devices (FADs) by purse-seine fleets (Chapter 8). The relative importance of skipjack, yellowfin and bigeye tuna in the total catch from the EEZs of PICTs[iii] reflects the proportions from the WCPO described above[iv].

Between 1999 and 2008, the overwhelming majority of the surface catch was taken in the EEZs of the Parties to the Nauru Agreement (PNA)[v] (**Table 12.1**). The average volumes and values of fish landed over this 10-year period are a reasonably good indication of the relative importance of the catches in each EEZ because they even out some of the El Niño and La Niña conditions that influence the distribution of skipjack tuna and fishing effort across the region (Chapter 8). Nevertheless, it should be noted that the average total catch and value for this 10-year period is now considerably lower than the more recent annual catches due to the increase in purse-seining operations (**Figure 12.3**).

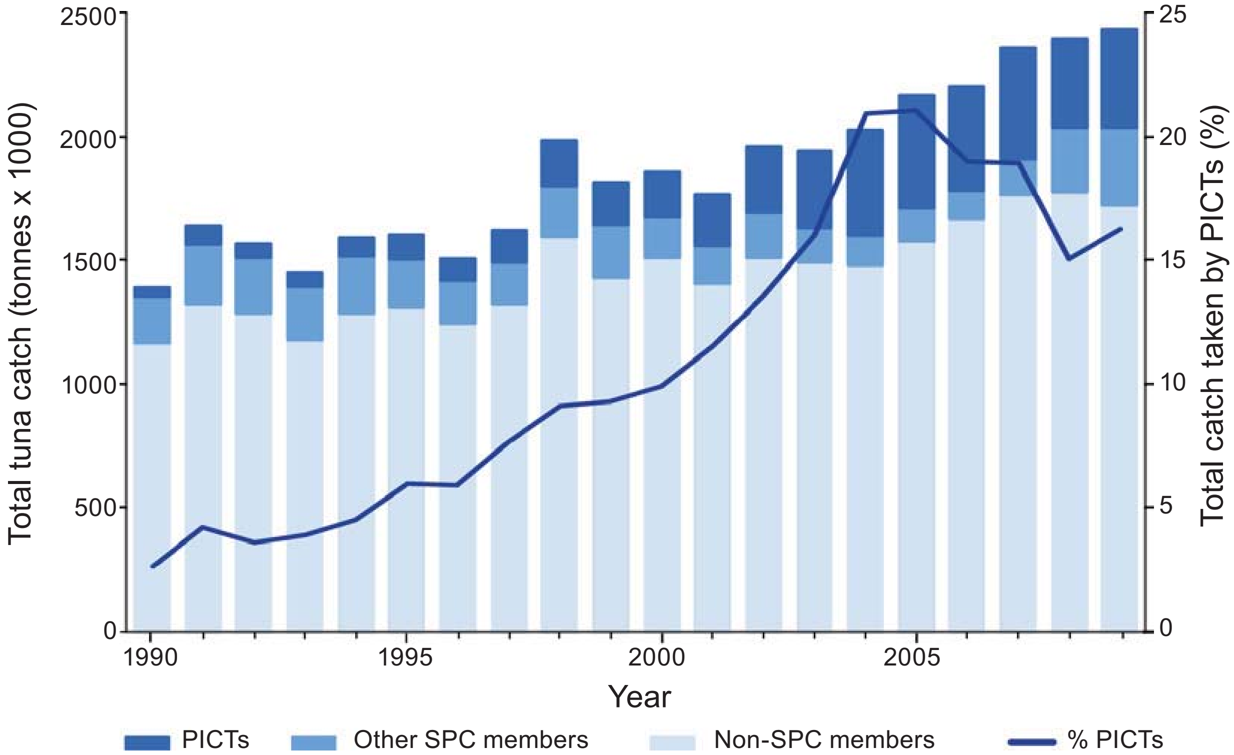


Figure 12.1 Catches of the four main species of tuna combined from the Western and Central Pacific Ocean between 1990 and 2009 taken by fleets operating from Pacific Island countries and territories (PICTs); other SPC members (mainly USA, but also Australia and New Zealand); and non-SPC members (mainly Indonesia, Philippines, and distant water fishing nations, notably Japan, Korea, China and Taiwan/ROC). The percentage of catch taken by PICTs each year is also shown.

iii The area approximating 25°N to 25°S and 130°E to 130°W (see **Figure 1.1** in Chapter 1).

iv See Supplementary Table 12.1, www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf

v PNA members are: Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu (www.pnatuna.com).

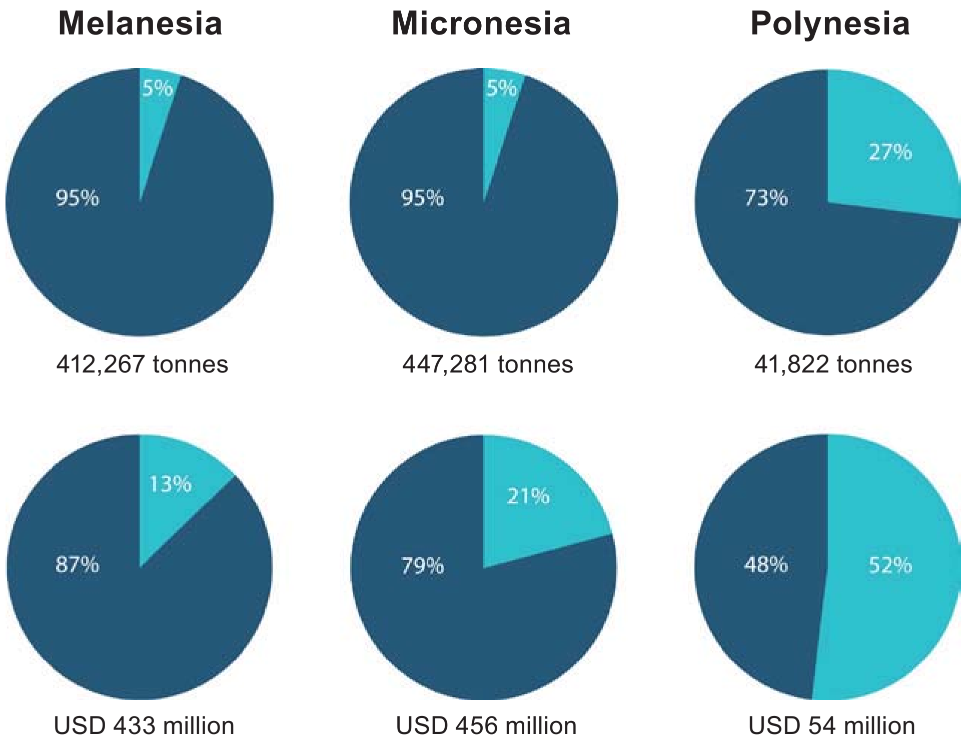


Figure 12.2 Average volume (tonnes), and average value (USD), of the total tuna catch from the exclusive economic zones of Pacific Island countries and territories in Melanesia, Micronesia and Polynesia taken by the surface (■) and longline (■) tuna fisheries over the period 1999–2008.

Striking trends within the surface fishery are that (1) catches by DWFNs within the EEZs of PICTs where the abundances of skipjack and yellowfin make industrial fishing economically viable usually far exceed those by domestic fleets; and (2) fleets flagged in the Federated States of Micronesia (FSM), Kiribati, Marshall Islands and Vanuatu catch far more tuna outside their EEZ (**Table 12.1**). In reality, however, some of these national fleets do not represent true domestication of the industry because vessels are registered in PICTs but are effectively owned and controlled by companies based elsewhere. Indeed, the recent decline in the percentage of the catch taken by PICTs (**Figure 12.1**) reflects re-flagging of some purse-seine vessels to other countries.

It is also important to note that, except for American Samoa and PNG, and to some extent Solomon Islands, the indicative port landings (**Table 12.1**) represent transshipments by vessels transporting fish to canneries outside the region.

The average annual value of tuna caught in the surface fishery by the national fleet in PNG exceeded USD 100 million between 1999 and 2008, and ~ USD 20 million in Solomon Islands (**Table 12.1**). However, these long-term averages mask recent trends[8]. The total value of tuna catches remained relatively static between 1999 and 2005 because oversupply of the global market depressed prices, but then increased substantially over the following three years when the price for canning tuna improved. For example, the average value of catches from the purse-seine fishery in PNG between 1999 and 2005 was USD 206 million, increasing to an average of USD 657 million from 2006–2008.

Table 12.1 The average annual catch and value of the surface tuna fishery for national fleets and foreign fleets in the exclusive economic zones (EEZs) of Pacific Island countries and territories (PICTs) where the fishery operated between 1999 and 2008. The average total volume and value of the catch made by national fleets across the Western and Central Pacific Ocean as a whole is also shown, together with average annual landings by national and foreign fleets at ports within PICTs. Note that New Caledonia, Commonwealth of the Northern Mariana Islands, Niue, Pitcairn Islands, Tonga and Wallis and Futuna are not included in this analysis because no catch was made in the EEZs of these PICTs by the surface fishery during this period. See Supplementary Table 12.1 for catch by species (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

PICT	Average annual catch (tonnes)			Average annual catch value (USD million)**			Average port landings (tonnes)***	
	National fleet		Foreign fleet	National fleet		Foreign fleet	National fleet	Foreign fleet
	EEZ	Region	EEZ	EEZ	Region	EEZ		
Melanesia								
Fiji	465	465	248	1.44	1.44	0.77	0	3939
PNG*	97,933	158,594	221,792	105	170.4	203	55,762	88,627
Solomon Islands*	20,829	22,369	13,446	19.7	21.1	46.7	8766	57,578
Vanuatu	0	43,523	77	0	43.5	0.06	0	193
Micronesia								
FSM*	3227	19,247	152,349	2.67	15.9	126	9796	196,053
Guam	0	0	17	0	0	0	0	0
Kiribati*	335	5332	180,851	0.28	4.52	153	132	61,068
Marshall Islands*	2756	35,777	22,530	2.44	31.7	20.0	32,511	121,524
Nauru*	0	0	63,063	0	0	52.4	0	2115
Palau*	0	0	1815	0	0	1.83	0	203
Polynesia								
American Samoa	0	0	49	0	0	0.04	0	107,620
Cook Islands	0	0	650	0	0	0.44	0	0
French Polynesia	623	636	80	0.52	0.53	0.07	172	87
Samoa	0	0	60	0	0	0.03	0	363
Tokelau	0	0	2664	0	0	2.00	0	0
Tuvalu*	0	0	26,379	0	0	22.6	0	0

* Parties to the Nauru Agreement; ** represents ex-vessel value calculated using the approach taken by Gillett (2009)[4], where prices provided by FFA (2009)[69] are discounted by 15% to account for transshipping costs with the exception of the locally-based fleet in PNG where no product is transshipped and therefore no discount is applied; *** representative values only, derived from logsheet, port sampling and landings data.

Contributions to gross domestic product and government revenue

Although large catches are made by the surface fishery in the EEZs of several PICTs, contributions to gross domestic product (GDP) are affected by whether the catches are landed in the country and, if they are landed, by the size of the national economy.

In PNG, where the national economy is large in regional terms, the significant surface fishery in the EEZ (which dominates catches from the western Pacific) averaged only 1.5% of GDP from 1999–2008, although it was 2.8% at the end of this period (**Table 12.2**). For the economies of Solomon Islands and FSM, the surface fishery made up 2.3% and 3.3% of GDP over the 10-year period, respectively, and increased to 3% for Solomon Islands in 2007 (**Table 12.2**).

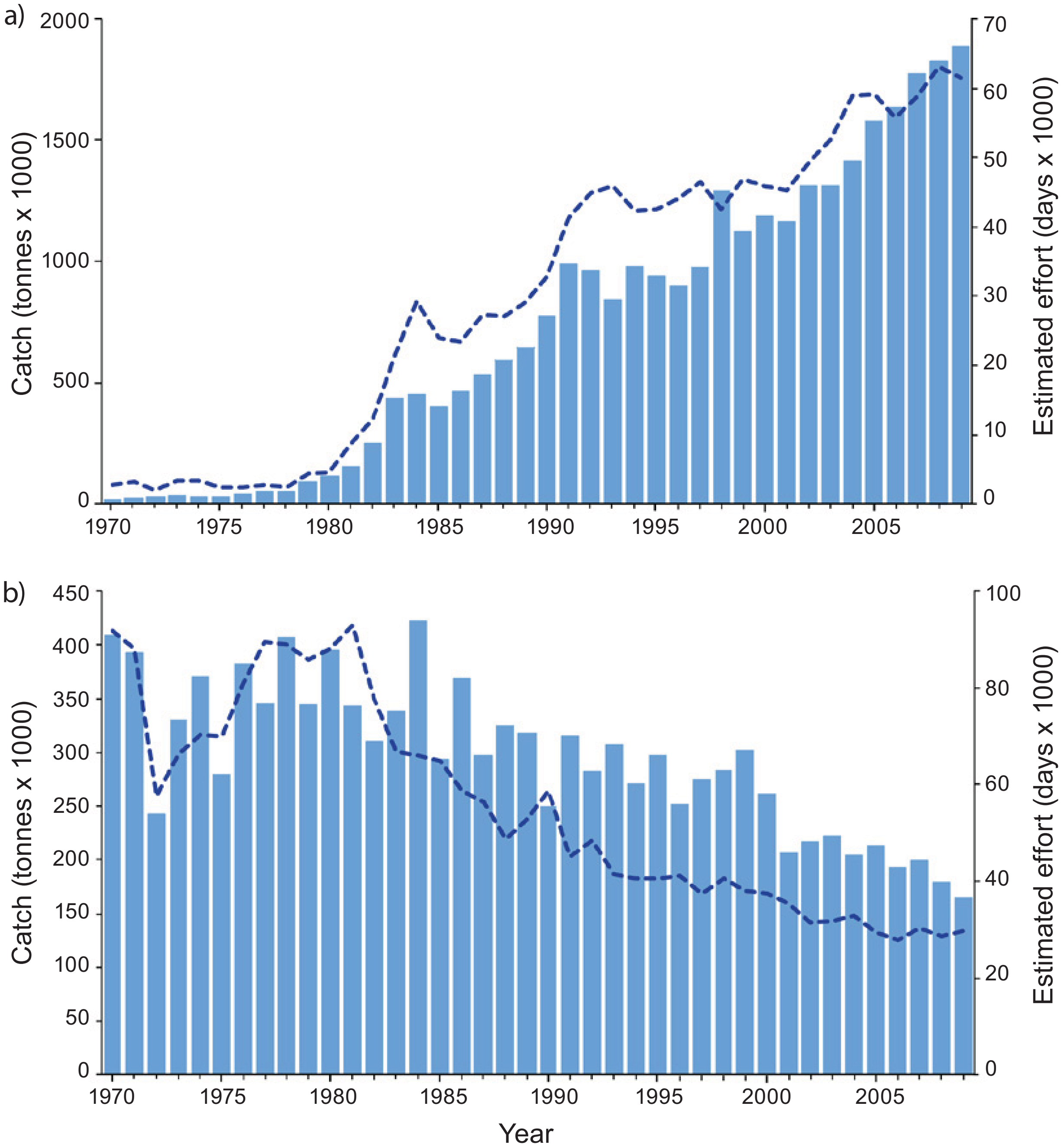


Figure 12.3 Changes in catch (columns) and effort (dashed line) by (a) the purse-seine fleet, and (b) the pole-and-line fleet, in the surface fishery for tuna in the Western and Central Pacific Ocean between 1970 and 2009 (source: Williams and Terawasi 2010)[8].

Contributions of the surface fishery to GDP have been greatest in the Marshall Islands, where they averaged > 10% over the 10-year period and were 21% in 2007 (**Table 12.2**). These substantial contributions are due to the large size of the local purse-seine fleet, and the limited opportunities for other economic activities in this small atoll nation. Despite the fact that purse-seine vessels flagged in Kiribati and Vanuatu make substantial catches within the region, the boats are not locally based and, according to international guidelines for calculating GDP, make no contribution to national GDP[4]. Similarly, vessels that offload to the cannery in American Samoa are not considered to be locally based – they come to Pago Pago primarily to discharge their catch[4].

It is important to note that the contributions from the surface fishery to GDP described above relate to fishing operations only and do not include any post-harvest activities. However, processing can be a significant part of GDP in some PICTs. American Samoa provides the best example, where the recent value of manufacturing outputs was 22.3% of GDP[9], worth around USD 100 million. When the value of post-harvesting of tuna is added to the fishing operations in Solomon Islands, the combined contribution to GDP increases to 4.6%, worth USD 22 million[10].

Whereas the surface fishery contributed to the GDP of relatively few PICTs, 15 countries and territories received fees from DWFNs for their purse-seine and pole-and-line fleets to fish within national EEZs[4,11] (**Table 12.2**). The payment of access fees by DWFNs is not captured in GDP calculations as it is a transfer of funds from outside the domestic economy. In 2007, access fees ranged from USD 132,000 for Tonga to USD 21.4 million for Kiribati (**Table 12.2**)[vi].

Foreign access fees are of great importance to many PICTs – they contributed between 3% and 42% of total government revenue for seven countries and territories in 2007 (**Table 12.2**). They are particularly important to the smaller economies within the PNA (Kiribati, Nauru and Tuvalu), and to FSM. Indeed, in some of these PICTs, government revenue exceeds GDP (**Table 12.2**). The level of access fees reflects both the distribution of fishing effort and catches – fees are normally negotiated as a percentage of the value of catches in the EEZ – as well as national policies. In certain PICTs, e.g. Tonga, some fees are received as a result of being part of the multilateral treaty between the US and members of the Forum Fisheries Agency[vii], even though no or very little catch is taken in their EEZ. Several other PICTs, including the French territories, do not generally favour access agreements and reserve part or all of the fishery for locally-based vessels.

Some governments also gain revenues from a variety of sources associated with purse-seine and pole-and-line fishing activity, including transshipment revenues and

vi See Supplementary Table 12.2 for access fees paid in other years, www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf

vii Members of FFA are: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, together with Australia and New Zealand.

licence fees paid by operators of domestic tuna vessels[4]. These revenues vary among countries but are usually less than access fees from DWFNs as a percentage of catch value.

Table 12.2 Contributions of the surface tuna fishery to gross domestic product (GDP), and total government revenue (GR) through payment of access fees by distant water fishing nations, to Pacific Island countries and territories (PICTs) in USD, and in percentage terms. Contributions to GDP relate only to fishing operations and do not include post-harvest activities. See Supplementary Table 12.2 for sources of estimates for GDP and GR and contributions to GDP and foreign access fees for other periods (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

PICT	GDP	Contribution to GDP: Locally based purse-seine and pole-and-line fleets				Total government revenue	Foreign access fee revenue 2007*a	
		Estimate based on 1999–2008 average		2007*				
	USD million	USD million	% GDP	USD million	% GDP	USD million	USD million	% GR
Melanesia								
Fiji	3290	0.7	0.02	0	0	920	0.26[b]	< 0.1
New Caledonia	8829	0	0	0	0	996	0	0
PNG	5708	85.2	1.49	161	2.82	2599	14.97[b]	0.6
Solomon Islands	457	10.5	2.31	14	3.07	267	11.76[b]	4.4
Vanuatu	500	0	0	0	0	79	1.36	1.7
Micronesia								
FSM	237	7.9	3.35	7.8	3.28	145	14.76	10.2
Guam	3679	0	0	0	0	428	0	0
Kiribati	71	0	0	0	0	51	21.36	41.9
Marshall Islands	156	15.8	10.16	32.7	20.95	93	1.95	2.1
Nauru	22	0	0	0	0	30	6.13[b]	20.4
CNMI	633	0	0	0	0	193	0	0
Palau	157	0	0	0	0	36	1.12	3.2
Polynesia								
American Samoa	462	0	0	0	0	155	0	0
Cook Islands	211	0	0	0	0	86	0.26[b]	0.3
French Polynesia	5478	0.3	< 0.01	nea	nea	865	0	0
Niue	10	0	0	0	0	12	0.26[b]	2.2
Pitcairn Islands	nea	0	0	0	0	7	0	0
Samoa	524	0	0	0	0	168	0.26[b]	0.1
Tokelau	nea	0	0	0	0	13	1.48[b]	11.4
Tonga	238	0	0	0	0	76	0.13[b]	0.2
Tuvalu	15	0	0	0	0	31	3.45	11.1
Wallis and Futuna	188	0	0	0	0	nea	0	0

* Derived from Gillett (2009)[4]; a = estimates are for aggregate access fee revenues for foreign pole-and-line, purse-seine and longline fleets as provided by Gillett (2009)[4]; b = PICTs which did not receive access fee revenues from foreign longline fleets between 2006 and 2008 or which usually receive > 90% of their total access fee revenue from foreign fleets operating in the surface fishery; nea = no estimate available.

12.2.1.2 The longline fishery

Volume and value

Longline vessels operate more widely across the WCPO than the purse-seiners in the surface fishery, and much of the catch from this lower volume/higher value fishery is taken outside the EEZs of PICTs in international waters[8]. Nevertheless, national longline fleets from 15 PICTs operate within their own EEZs, and relatively large catches (1400–6600 tonnes per year) are made by Cook Islands, Fiji, French Polynesia, New Caledonia, PNG and Samoa (**Table 12.3**). Longline fleets from several PICTs also fish elsewhere in the region. For example, vessels from the six PICTs listed immediately above take > 50% of their total catches outside their EEZs, and the fleet from Vanuatu takes > 85% of its landings in this way (**Table 12.3**).

Longline fishing by fleets from DWFNs spans an even greater number of PICTs. Longline vessels from DWFNs have operated at some stage in the EEZs of most of the 22 countries and territories, although catches from the waters of six PICTs are < 10 tonnes per year (**Table 12.3**). Catches by DWFNs are lower than the national fleet within the EEZs of nine PICTs and greater than those by the national fleet in 13 PICTs. Catches by DWFNs relative to the national fleet are particularly high in FSM, Kiribati, Marshall Islands, Palau, Solomon Islands and Vanuatu (**Table 12.3**). The most significant longline catches by DWFNs are made in Kiribati, where they averaged 8800 tonnes per year between 1999 and 2008.

Several PICTs land the majority of their longline catch at their own ports, although the Samoan vessels land much of their fish in American Samoa. Fleets from DWFNs mainly offload their catch in Fiji and American Samoa, although Palau, Marshall Islands, FSM and French Polynesia are also used to land large catches (**Table 12.3**). Albacore and yellowfin tuna dominate the catch in Melanesia, whereas bigeye and yellowfin tuna are caught most commonly in Micronesia, and albacore in Polynesia[viii].

Contributions to gross domestic product and government revenue

The lower volumes and values of fish caught by the longline fishery compared to the surface fishery (**Figure 12.2**) result in much more limited contributions to GDP and government revenue from longlining in most PICTs[ix]. In 2007, contributions to GDP from locally-based longline fleets ranged from 0.05–0.7% for 10 PICTs, however, they were significant for Niue (3.7%), Palau (3.4%) and Marshall Islands (2.0%)[4].

The contributions to government revenue from access fees paid by DWFN longline fleets are hard to estimate because they are often tied together with the fees for the surface fishery (**Table 12.2**). Access fees from longlining appear to have contributed ~ 6% of annual government revenue in Kiribati and > 1% in Cook Islands, FSM and Marshall Islands[11].

viii See Supplementary Table 12.3 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

ix See Supplementary Table 12.4 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

Table 12.3 The average annual catch and value of the longline tuna fishery for national and foreign fleets in the exclusive economic zones (EEZs) of Pacific Island countries and territories (PICTs) where the fishery operated between 1999 and 2008. The average total volume and value of the catch made by national fleets across the Western and Central Pacific Ocean as a whole is also shown, together with average annual landings by national and foreign fleets at ports within PICTs. See Supplementary Table 12.3 for catch by species (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

PICT	Average annual catch (tonnes)			Average annual catch value (USD million)*			Average port landings (tonnes)**	
	National fleet		Foreign fleet	National fleet		Foreign fleet	National fleet	Foreign fleet
	EEZ	Region	EEZ	EEZ	Region	EEZ		
Melanesia								
Fiji	6641	10,785	196	17.75	28.56	0.5	9995	11,274
New Caledonia	1840	1879	8	0	5.41	0	1673	16
PNG	2763	2769	134	10.65	10.68	0.44	2178	107
Solomon Islands	519	529	4186	2.33	2.37	12.54	496	140
Vanuatu	953	7156	4237	2.46	18.11	10.02	8	36
Micronesia								
FSM	592	978	5553	3.15	5.19	26.05	567	1281
Guam	0	0	0.3	0	0	0	0	56
Kiribati	0.6	5.9	8808	0.04	0.04	37.82	0	44
Marshall Islands	50	49	2921	0.3	0.3	14.4	54	2293
Nauru	5.2	5.2	1.4	0.02	0.02	0.01	0	0
CNMI	0	0	0.1	0	0	0	0	0
Palau	26	26.1	2380	0.14	0.13	12	19	3299
Polynesia								
American Samoa	0	0	407	0	0	0.95	2630	10,284
Cook Islands	1432	1567	72	3.56	3.95	0.16	176	31
French Polynesia	4355	4626	294	12.17	12.26	1.03	3639	1078
Niue	55	55	18.3	0.15	0.16	0.04	46	16
Pitcairn Islands	0	0	0.5	0	0	0	0	0
Samoa	2867	3531	3	6.45	7.99	0	843	109
Tokelau	0	0	5.5	0	0	0.02	0	0
Tonga	852	981	137	0.26	2.83	0.31	725	19
Tuvalu	0	0	651	0	0	2.32	0	2

* Represents ex-vessel value calculated using the approach taken by Gillett (2009)[4], where prices provided by FFA (2009)[69] are discounted by 30% to account for transportation costs and increased by 10% to account for bycatch sales. Cook Islands is the exception due to the atypical marketing channels for the fish caught there; ** information provided by SPC Oceanic Fisheries Programme.

12.2.2 Plans to increase contributions from industrial tuna fishing

For decades, PICTs have identified the region's tuna resources as one of their major assets – in the case of some countries it would seem to be the only renewable natural resource which can support economic development[12].

From the 1950s to the 1970s, operational bases for US and Japanese fishing and processing companies were established in American Samoa, Fiji and Solomon Islands. Despite some changes of ownership, these facilities are still important centres for processing tuna. In the 1980s and 1990s, several other PICTs set up national tuna fishing companies, however, none of these government-owned operations proved to be profitable on a sustained basis due to a range of operational and management problems. Locally-owned longline fishing operations were also established by the private sector in a number of PICTs in the 1990s, mainly in the south of the region. These operations enjoyed greater success but have faced difficult economic conditions in recent years and only well-managed companies in favourable locations have survived[13].

Since the 1980s, however, the tuna industry in the WCPO has been dominated by two trends (1) the growth of the purse-seine fishery, using large capital-intensive vessels which can range throughout the region and transship their frozen catches for transport to markets anywhere in the world (**Figure 12.3**); and (2) the development of large efficient tuna processing hubs in countries like Thailand and the Philippines, with plentiful low-cost labour. Many Pacific Island countries facilitated this development through their willingness to sell access to their EEZs in exchange for much-needed government revenue. As a result, the majority of the catch is still taken by foreign vessels and shipped outside the region for processing.

In the last decade there has been renewed interest by a number of PICTs in capturing wider economic benefits from tuna resources, particularly employment, by attracting foreign investment into locally-based fishing and processing operations. This has been encouraged recently by the 'DevFish' project[x] funded by the European Union (EU), which has demonstrated that the economic gains for PICTs from a tonne of tuna caught in the region are much greater from locally-based longlining or purse-seining operations when the catches are landed for processing onshore[14,15]. In the last three years alone, > USD 60 million has been invested in new tuna processing plants in the region[16] and several new facilities are proposed – mainly in PNG and Solomon Islands.

Although the opportunities to increase total catches are limited, it is now apparent that each additional 100,000 tonnes of tuna retained from the surface fishery for processing in the region can create ~ 7000 new jobs[17]. This is an important consideration in PICTs where population growth has outpaced the rate at which jobs are created. However, the tuna industry is a globalised business and responds quickly to opportunities created by changes in the economic environment, as well as to technological advances. Therefore, investments in the region are sensitive to the prevailing economic conditions. Recent examples include the Interim Economic Partnership Agreement (IEPA) between PNG and the EU, which has promoted increased investment, and the mandated minimum wage rates in American Samoa, which threaten the future of both the long-established canneries there[18].

x www.ffa.int/devfish

The eight PNA countries are currently exploring collective ways to promote development of domestic tuna industries, including a possible tuna corporation or cartel[19]. This grouping, which has often led regional fisheries initiatives, established an independent office in Marshall Islands in 2010 to further the interests of its members. It must be recognised, however, that large-scale onshore processing is only viable in those few PICTs with adequate land and fresh water, and low labour costs. Other mechanisms, such as transferring the nominal ownership of fishing vessels to Pacific Island governments, have yet to demonstrate economic benefits and may prove to be less advantageous than access agreements in some cases.

12.2.3 Contributions from coastal fisheries

Coastal fisheries include a range of fishing methods that catch demersal fish (bottom-dwelling fish associated with coral reef, mangrove and seagrass habitats), nearshore pelagic fish, and a wide variety of invertebrates (Chapter 9). Although much of the fishing effort is by subsistence fisheries (Section 12.3), several species of demersal fish, nearshore pelagic fish and a limited range of invertebrates are also caught for sale at local markets and, in some cases, for export (e.g. sea cucumbers, trochus, aquarium fish and deepwater snappers). Fishing operations are typically artisanal and small-scale, with boats and other assets often owned by the fishers themselves.

Volume and value

In 2007, the total catch of commercial coastal fish and invertebrates from the region was estimated to be almost 45,000 tonnes, with a landed value of USD 165 million[4] (**Table 12.4**). Demersal fish are estimated to make up ~ 60%, nearshore pelagic fish 32% and invertebrates 8% of the total commercial catch (Chapter 9). However, these calculations underestimate the importance of sea cucumbers (exported as processed bêche-de- mer) because the weight of bêche-de-mer is usually < 10% of live weight[20]. In 2007, ~ 1500 tonnes of bêche-de-mer were exported from the region (Chapter 9) and so another ~ 13,500 tonnes needs to be added to the live weight of invertebrates caught. When the total catches from the three categories of coastal fisheries in **Table 12.4** are adjusted for the live weight of sea cucumbers, the invertebrates make up ~ 30% of the total catch. Based on the overall landed values of coastal commercial and subsistence catches for the region in 2007[4], the important contribution of high-value bêche-de-mer to commercial catches makes the average landed value of commercial coastal fisheries products (~ USD 3.70 per kg), twice that of fish and invertebrates caught for subsistence (~ USD 1.80 per kg).

Contributions to gross domestic product and government revenue

Due to the relatively high value-added ratio for small-scale fishing operations, coastal fisheries are estimated to have contributed ~ USD 105 million to the combined GDP of PICTs in 2007[4] (**Table 12.4**). Although the contributions to GDP from coastal fisheries are dwarfed by those from the surface tuna fishery in Marshall Islands, PNG and Solomon Islands, and are somewhat lower for FSM, they exceed those from the surface tuna fishery in the other 18 PICTs (**Tables 12.2** and **12.4**). In the case of some of the latter PICTs, this is because the catch from the surface fishery by DWFNs does not

Table 12.4 Estimated annual catches of the main components of commercial coastal fisheries (demersal fish, nearshore pelagic fish, targeted invertebrates) in 2007, together with the total volume and value of the catch. Contribution of the total commercial catch to GDP for Pacific Island countries and territories (PICTs), calculated by the value added ratio used by Gillett (2009)[4], is also shown. See Chapter 9 for the method used to estimate the catches of commercial demersal fish, nearshore pelagic fish and invertebrates. See Supplementary Table 12.2 for source of GDP estimates at each PICT (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

PICT	GDP (USD million)	Commercial coastal fisheries catch						
		Demersal fish (tonnes)	Nearshore pelagic fish (tonnes)	Inverte-brates (tonnes)	Total catch (tonnes)	Total value (USD million)	GDP con-tribution (USD million)	% GDP
Melanesia								
Fiji	3290	6210[a]	2660	630	9500	33.75	18.56	0.56
New Caledonia	8829	840	210	300[b]	1350	8.69	5.65	0.06
PNG	5708	2640	1760	1300[c]	5700	27.03	16.99	0.30
Solomon Islands	457	1050[e]	1250[d]	950	3250	3.31	2.19	0.48
Vanuatu	500	280[e]	188	70	538	2.18	1.52	0.30
Micronesia								
FSM	237	1660	1110	30	2800	7.56	5.67	2.39
Guam	3679	14	30	0	44	0.19	0.12	0.00
Kiribati	71	5430[e]	1510	60	7000	18.49	12.02	16.93
Marshall Islands	156	567[e]	380	3	950	2.90	2.17	1.39
Nauru	22	100	100	0	200	0.84	0.50	2.29
CNMI	633	115[e]	116	0	231	0.95	0.60	0.09
Palau	157	460	305	100	865	2.84	1.99	1.27
Polynesia								
American Samoa	462	24	11	0	35	0.17	0.11	0.02
Cook Islands	211	53[e]	80	0	133	1.03	0.67	0.32
French Polynesia	5478	1566[e]	2332	104	4002	23.00	12.65	0.23
Niue	10	5	5	0	10	0.06	0.03	0.30
Pitcairn Islands	nea	5	0	0	5	0.04	0.02	nea
Samoa	524	2479	1650	0	4129	19.56	15.65	2.99
Tokelau	nea	0	0	0	0	0	0	nea
Tonga	238	3330[f]	370	0	3700	11.29	6.98	2.93
Tuvalu	15	147	79	0	226	0.62	0.28	1.87
Wallis and Futuna	188	83	21	17	121	1.21	0.78	0.42
Total		**27,058**	**14,167**	**3564**	**44,789**	**165.69**	**105.15**	

a = Includes deepwater snappers and aquarium fish; b = includes mud crabs and spiny lobsters sold on local market; c = includes hundreds of tonnes of penaeid shrimp; d = includes 800 tonnes of baitfish, and aquarium fish; e = includes aquarium fish; f = includes 700 tonnes of deepwater snappers, and aquarium fish; nea = no estimate available.

come ashore and therefore makes no contribution to GDP. In comparison, commercial coastal fisheries account for ~ 17% of GDP in Kiribati and 1.3–3% of GDP in another seven PICTs (**Table 12.4**). The contribution of commercial coastal fisheries to GDP also exceeds that from the tuna longline fishery in all PICTs except American Samoa, Niue and Palau. Coastal fisheries make little contribution to government revenue because the artisanal, small-scale nature of fishing operations is not licensed in most PICTs. A few PICTs (e.g. Fiji, Kiribati and Solomon Islands) have from time to time collected modest export duties or other taxes on the export of bêche-de-mer and trochus.

Sea cucumbers, Solomon Islands

Photo: Louise Goggin

12.2.4 Plans to increase contributions from coastal fisheries

The opportunities to increase production from commercial coastal demersal fisheries are limited. Many demersal fisheries for cash income in the region are considered to be fully exploited or overexploited[21,22] (Chapter 9). Where stocks of demersal fish are still in good condition, increasing human populations and difficult economic conditions are likely to drive coastal communities in several PICTs to use these resources directly for subsistence, unless increased access can be provided to the fish needed for food security through development of fisheries for nearshore pelagic fish (tuna) and pond aquaculture[3] (Section 12.3). In remote, sparsely populated areas of some PICTs, e.g. French Polynesia, Kiribati and Marshall Islands, there are still abundant stocks of commercially-valuable coastal fish and invertebrates. However, the costs of transporting catches from such areas to distant local markets can be prohibitive and there is little prospect of them contributing to economic development. Also, there is increasing interest in conserving these areas for non-extractive use. The recently established Phoenix Islands protected area in Kiribati is a case in point.

The situation for the invertebrates targeted by commercial coastal fisheries, particularly sea cucumbers and trochus, is even more serious for many PICTs. Populations of these valuable species have been overfished to the point where the adult spawning biomass is well below the threshold levels needed to provide regular substantial harvests[20,23–25] (Chapter 9). In recognition of the need to rebuild the spawning stocks to more productive levels, several PICTs (e.g. Marshall Islands, Palau, PNG, Samoa, Solomon Islands, Tonga) have, at various times, implemented moratoriums on fishing for sea cucumbers. With the exception of a few PICTs where stocks of trochus and sea cucumbers are still healthy (e.g. New Caledonia), effective management measures are needed to rebuild populations before greater and sustainable economic benefits can be expected from invertebrate fisheries for export commodities (Chapters 9 and 13). In most cases, this will involve a reduction in contributions to GDP in the short- to medium-term while stocks are rebuilt.

There are, however, options to increase production of resources currently harvested by coastal commercial fisheries. These options, which promise to deliver greater economic benefits under sustainable management, are outlined below.

- **Increase the catch of tuna from nearshore waters:** Skipjack and yellowfin tuna, together with a range of other large pelagic oceanic species, are already caught regularly by coastal fisheries in many PICTs (Chapter 9), either by trolling near the surface, or by handlining in deeper water. Stocks of skipjack tuna are robust (Chapter 8) and increased catches by small-scale fishers are likely to have a negligible impact on the resource compared to the industrial harvest. Even greatly increased catches of yellowfin tuna by artisanal coastal fisheries are likely to be minor compared to the current harvests made by the industrial fisheries (Section 12.2.1). Nevertheless, catches by coastal fisheries should be taken into account in assessing and monitoring regional stocks of skipjack and yellowfin tuna.

  The production and profitability of small-scale coastal fisheries for tuna can be increased by (1) improved handling of the catch; (2) investment by governments in the infrastructure needed to access higher-value markets; (3) deployment of low-cost, anchored FADs in coastal waters in depths < 1000 m; and (4) training programmes to improve the fishing skills for fishers who have focused previously on demersal fish. Investments in inshore, anchored FADs promise to increase catches greatly[2] (Chapter 13), however, care needs to be taken to position these FADs where they will attract mainly tuna and other oceanic fish. Otherwise, inshore FADs may increase the fishing mortality of Spanish mackerel, and other pelagic fish species dependent on coastal habitats, to unsustainable levels (Chapter 9).

- **Make greater use of small pelagic fish:** The wide range of small pelagic species (e.g. anchovies, pilchards, scads and flyingfish) that occur in nearshore waters throughout much of the tropical Pacific (Chapter 9) are not widely used for food. They are popular food fish elsewhere in the world and, as the demand for fish grows in many PICTs as a result of rapidly growing human populations

(Section 12.3), these species could help supply the fish required through sales at local markets. Fusiliers (*Caesio* spp.), which occur in the mid water above coral reefs, are also abundant in many PICTs (Chapter 9) and are a popular food fish in Okinawa, Japan. In some PICTs, fishers will require training in how to catch small pelagic fish using methods such as 'bouke-ami' and 'bagan', which do not damage coastal fish habitats or result in significant bycatch (Chapter 9).

- **Expand the marine aquarium trade:** The collection of fish, corals and other invertebrates for export to aquarium enthusiasts overseas has become a multi-million dollar business in PICTs over the last 20 years[25,26]. The trade is attractive because it provides an income from species which are not used for food, and can be managed sustainably through controls on a small number of exporters (especially important in the case of corals, which could otherwise be overexploited). Resource surveys indicate that there is potential to develop enterprises to export tropical marine ornamental products in several PICTs[27]. Elsewhere, transport costs and communications are a constraint.
- **Non-extractive uses:** Developing sustainable ways to harvest a greater range and quantity of fish and invertebrates is not the only way to increase economic returns from coastal fisheries resources. Non-extractive uses of coastal fish habitats and fish stocks, such as dive-based tourism in marine protected areas[28–30], may offer opportunities for economic development that also help protect spawning biomass and replenish stocks in surrounding areas open to fishing[31,32]. Sportfishing based on coastal fish can also provide employment and income in a way that has minimal impact on the resource.

12.2.5 Contributions from aquaculture

Development of aquaculture in the region has been limited compared to other parts of the world[4,33] (Chapter 11). The exceptions are French Polynesia and New Caledonia. The value of cultured black pearls from French Polynesia was USD 173 million in 2007[33], although pearl farming contributed < 1% to GDP because the economy is large[4]. In New Caledonia, shrimp farming produced ~ 1850 tonnes of high-quality shrimp valued at USD 29 million in 2007[33]. The value added from fisheries and aquaculture combined is also < 1% of GDP in New Caledonia due to the large size of the economy. Most of the other aquaculture industries in the region, except for pearl farming in Cook Islands, are at a fledgling stage, and the combined value of the various commodities was estimated to be USD 8 million in 2007[33].

12.2.6 Plans to increase contributions from aquaculture

Slow development of many aquaculture commodities in PICTs has been attributed to the lack of policy and legislation frameworks and planning to overcome technical, logistical and socio-economic constraints (Chapter 11). However, the past is not necessarily a guide to the future of aquaculture in the tropical Pacific. The regional

'Aquaculture Development Plan'[34], and a series of national aquaculture development plans[35–39], promise to put aquaculture in PICTs on a new footing – there is potential to increase production of several of the existing commodities in the region, and scope to produce new products.

The main prospects are thought to be (1) increasing the value of pearl production in Cook Islands, Fiji, FSM, Marshall Islands and PNG, and launching commercial pearl farming in Kiribati and Solomon Islands; (2) doubling the production of shrimp in New Caledonia and developing enterprises to help meet local demand in Fiji and PNG; (3) scaling-up the production of seaweed in Solomon Islands; (4) establishing intensive pond aquaculture for tilapia in peri-urban areas in Fiji, PNG, Solomon Islands and Vanuatu to provide fish for rapidly growing urban populations; (5) growing-out wild-caught juvenile milkfish, rabbitfish and freshwater prawns for local markets; (6) using the region's pristine image and environmentally friendly farming methods to increase the market share of cultured tropical marine fish and invertebrates for the ornamental trade; (7) forging stronger links between tourism and local aquaculture products; and (8) possible production of marine algae for biofuels (Chapter 11).

12.3 Food security

12.3.1 Current fish consumption

Most PICTs have an extraordinary dependence on fish[xi] for food security due to limited access to other sources of animal protein, particularly in rural areas[3,4,40] (**Table 12.5**). Although comprehensive data are not available for the entire region, recent national annual consumption per person by rural communities exceeds 50 kg in many PICTs, and is 60–145 kg in coastal communities in 11 PICTs (**Table 12.5**). Fish provides 51–94% of animal protein in the diet in rural areas, and 27–83% in urban areas, across the region. PNG is the exception, where the large inland population generally has much less access to fish, except for communities living near rivers (Chapter 10). Importantly, the great majority of fish for food security in the region is derived from coastal subsistence fishing – in 14 PICTs, 52–91% of the fish eaten in rural areas is caught by the household from coral reefs and other coastal habitats (**Table 12.5**) (Chapter 9). High levels of subsistence fishing are also common in urban areas in many of the smaller PICTs. The high dependence on fish by Pacific communities is a stark contrast with average global fish consumption of fish per person, which is 16–18 kg per year[41,42].

Due to the high dependence on fish for animal protein, and the widespread participation of households in fisheries (Section 12.4), subsistence fishing in coastal and freshwater habitats produced three times as much fish as commercial fishing in coastal waters in 2007[4]. Even when the production of bêche-de-mer is converted

xi Fish is used here in the broad sense to include fish and invertebrates.

to live weight, subsistence fishing produced 2.25 times the volume of fish taken in small-scale commercial fisheries in 2007.

Fish is a cornerstone of food security for many Pacific communities[43]. Due to the lack of agricultural systems capable of producing large quantities of animal protein in the region, fisheries resources must continue to be allocated for this purpose in the future[44]. The problem is that more fish is required by the rapidly growing human populations in the tropical Pacific, particularly in Melanesia (Chapter 1). By 2035, ~ 320,000 tonnes of fish will be needed across the region to provide the fish recommended for good nutrition[40], or to maintain traditional patterns of fish consumption (**Table 12.5**). This represents an increase of more than 80% in the fish required for food security in 2010.

12.3.2 Plans to maintain fish consumption

The vital role that fish plays in food security in many PICTs has led to plans to provide the fish required in the future. These plans are based on identifying how much fish people should be eating for good nutrition, assessing how much they eat now, forecasting how much fish will be needed as human populations increase, and identifying how to provide access to more fish where shortfalls in the productivity of coastal fisheries are projected to occur[3].

Based on the recommendation from the SPC Public Health Programme that people in the region should eat 35 kg of fish per year to ensure they obtain the protein needed for good health, or to maintain the traditionally greater rates of fish consumption in several PICTs, substantial quantities of fish will be needed across the region in the coming decades, particularly in Melanesia[3,40] (**Table 12.5**). In nine of the 22 PICTs, coastal fisheries are not expected to be able to meet this future demand for fish and the gap between the fish required and the fish expected to be available from coastal fisheries (and freshwater fisheries in some cases) will be substantial. In another seven PICTs, it may not be economical to transport fish to urban centers from remote, productive coral reefs. If so, future demand for fish in the rapidly growing urban centres in these PICTs may not be fulfilled. The PICTs in each of these two categories are listed in Section 12.8.

Fortunately, the rich tuna resources of the region, and the high levels of rainfall in tropical Melanesia, provide the potential to fill this gap through (1) increasing access to tuna by the coastal nearshore pelagic fishery through the use of low-cost, anchored FADs; (2) using small tuna formerly discarded at sea to provide fish at low prices for rapidly growing and often poor urban populations; and (3) developing pond aquaculture for suitable species of freshwater fish both in rural areas and on the outskirts of urban centres[3,45]. In addition, there appears to be scope to increase the harvests of small fish species in the nearshore pelagic component of coastal fisheries

(Section 12.2.4) (Chapter 9). Care will be needed in choosing appropriate options for filling the gap. For example, inshore FADs will not be effective in transferring subsistence fishing effort from demersal fish to tuna everywhere. They should be located in places where they attract mainly tuna and, preferably, where people can paddle to them. Issues involved in planning which options to use are discussed in Chapter 13.

Table 12.5 Estimates of annual fish consumption per person, percentage of animal protein in the diet derived from fish, and percentage of fish consumed caught by subsistence fishing, in Pacific Island countries and territories (PICTs). The amount of fish needed for food security in 2035 is also shown (source: Bell et al. 2009, Gillett 2009)[3,4]. Fish is used here in the broad sense to include fish and invertebrates. Blank spaces indicate that no estimate was available.

PICT	Fish consumption per person (kg)				Animal protein in diet (%)		Subsistence catch (%)		Fish needed for food by 2035 (tonnes)
	National	Rural	Urban	Coastal*	Rural	Urban	Rural	Urban	
Melanesia									
Fiji	21	25	15	113			52	7	34,200[a]
New Caledonia	26	55	11	43			91	42	11,700[a]
PNG	13	10	28	53			64		140,700[b]
Solomon Islands	33	31	45	118	94	83	73	13	33,900[a]
Vanuatu	20	21	19	30	60	43	60	17	14,800[a]
Micronesia									
Guam	27								8800[a]
FSM	69	77	67	96	80	83	77	73	7300[c]
Kiribati	62	58	67	115	89	80	79	46	9000[c]
Marshall Islands	39								2200[a]
Nauru	56			62	71	71	66	66	790[c]
CNMI									4700[a]
Palau	33	43	28	79	59	47	60	35	800[a]
Polynesia									
American Samoa		63							3100[a]
Cook Islands	35	61	25	79	51	27	76	27	600[a]
French Polynesia	70	90	52	61	71	57	78	60	23,200[c]
Niue	79			50			56	56	100[c]
Pitcairn Islands	148								10[c]
Samoa	87	98	46	94			47	21	17,600[c]
Tokelau	~ 200								250[c]
Tonga	20			85			37	37	4000[a]
Tuvalu	110	147	69	146	77	41	86	56	1400[c]
Wallis and Futuna	74			56			86	86	1000[c]

* Applies to households in coastal fishing communities at > 4 sites; a = based on recommended fish consumption of 35 kg per person per year; b = based on the recent national average of 13 kg per person per year, rather than 35 kg, to reflect the difficulties of distributing fish to the large inland population; c = based on recent traditional levels of fish consumption (source: Bell et al. 2009)[3].

It is also important to recognise the link between food security and opportunities to earn income from catching and selling fish[3,46] (Section 12.4). Households that also earn income from selling fish have the resources to buy food to supplement the crops they grow and the fish they catch themselves. The pervasive importance of coastal fisheries as a source of income in the region (Chapter 9) should help to make coastal communities resilient to times when severe weather events damage crops and prevent fishing.

Photo: Christophe Launay

Small pelagic fish – an additional source of food

12.4 Livelihoods

12.4.1 Existing opportunities to earn income based on fisheries and aquaculture

Although there is little consistency across the region in the way information is kept on the proportions of people working full-time or part-time in fisheries and aquaculture[4], it is evident that employment in the sector is relatively important compared to many other parts of the world. For example, in American Samoa and French Polynesia, fisheries and aquaculture directly or indirectly provide > 20% of paid jobs due to the establishment of tuna canneries and black pearl farming, respectively[4].

Large numbers of formal full-time and part-time jobs have also been created through tuna processing in PNG, Solomon Islands and Fiji (**Table 12.6**), although they represent only a low percentage of total employment in these PICTs due to their relatively large populations (Chapter 1). Aquaculture has also provided large numbers of jobs in rural areas of Cook Islands and New Caledonia (**Table 12.6**). In general, however, most of the formal employment in the sector is associated with the tuna fishery and typically accounts for 1–3% of the workforce in a range of PICTs[4].

Table 12.6 Number of jobs in Pacific Island countries and territories (PICTs) on tuna vessels and in shore-based operations (e.g. canneries). Also shown is the average percentage of households in 4–5 coastal communities in each of 17 PICTs that earned their first or second income from fishing between 2002 and 2008, and the number of jobs in aquaculture (including opportunities to earn income) (source: Gillet 2009, Philipson 2007, Ponia 2010, SPC PROCFish Development Project)[4,13,33].

PICT	Local jobs on tuna vessels			Local jobs in shore-based processing of tuna			Coastal household earnings from fishing (%)			Jobs in aqua-culture
	2002	2006	2008	2002	2006	2008	First income	Second income	Both incomes	
Melanesia										
Fiji	893	330	150	1496	2200	1250	69.8	23.5	93.3	550
New Caledonia	Undetermined number of jobs						23.4	22.8	46.2	560
PNG	460	110	440	2707	4000	8550	53.3	32.5	85.8	> 10,000[a]
Solomon Islands	464	66	107	422	330	827	29.1	31.8	61.0	610
Vanuatu	54	20	30	30	30	30	21.4	39.8	61.1	30
Micronesia										
FSM	89	36	25	131	24	140	47.9	4.6	52.5	20
Guam	Undetermined number of jobs						nea	nea	nea	20
Kiribati	39	15	15	47	80	70	33.3	24.8	58.1	10
Marshall Islands*	5	0	25	457	100	116	36.0	17.6	53.6	5
Nauru	5	0	0	10	2	0	4.9	17.1	22.0	nea
CNMI	Undetermined number of jobs						nea	nea	nea	12
Palau	1	0	0	11	5	20	10.2	15.7	25.9	5
Polynesia										
American Samoa**	nea	nea	nea	nea	4757	nea	nea	nea	nea	15
Cook Islands	50	15	12	15	15	10	12.3	7.8	20.1	450
French Polynesia	Undetermined number of jobs						15.4	11.3	26.7	5000
Niue	5	0	0	0	14	18	1.4	8.7	10.1	0
Pitcairn Islands	No jobs based on tuna						nea	nea	nea	0
Samoa	674	110	255	108	90	40	24.2	26.6	50.8	16
Tokelau	No jobs based on tuna						nea	nea	nea	0
Tonga	161	75	45	85	35	35	41.5	4.7	46.2	20
Tuvalu	59	20	65	36	10	10	24.0	24.4	48.4	0
Wallis and Futuna	No jobs based on tuna						21.1	23.2	44.3	0
Total (average)	**2959**	**797**	**1169**	**5555**	**11,692**	**11,116**	**(27.6)**	**(19.8)**	**(47.4)**	**17,323**

* The loining plant in Majuro began operation after the period covered by the 2008 survey; ** number of jobs only available for 2006 but assumed to be about the same in 2002 and 2008; a = estimate by the National Fisheries Authority, Papua New Guinea, which includes > 10,000 households involved in pond aquaculture in inland areas and > 60 jobs in seaweed farming; nea = no estimate available.

The growth in employment based on tuna processing has been significant, however, the overall impact of the changes underway in the tuna industry on total earnings is uncertain because many jobs on fishing vessels have been lost in recent years (**Table 12.6**). Employment on longline vessels in particular has decreased as many of the boats owned by PICTs have stopped operating, and locally-based foreign longliners often use crew from Asian countries with lower wage expectations. In addition, most of the jobs in canneries are for low wages.

Overall, > 12,000 people in the region were employed directly on tuna fishing vessels or in processing operations in 2008[4,7] (**Table 12.6**). However, based on the number of associated jobs in government and the private sector in American Samoa[4], twice as many people could be employed indirectly as a result of tuna fishing and processing.

The contribution of coastal fisheries to livelihoods has been mainly through the informal economy, where self-employed artisanal and small-scale fishers harvest a wide range of fish species (Chapter 9) for sale at local markets, or sell fish that is surplus to household needs. But the informal nature of these activities should not be used to measure their significance – large numbers of people are engaged in coastal fisheries for their livelihoods across the region[4]. Perhaps the best measure of the significance of coastal fisheries to income earning opportunities in the region comes from the socio-economic surveys of 4–5 coastal communities in each of 17 PICTs during the SPC PROCFish Development Project[25]. Those surveys revealed that an average of 47% of households derived either their first or second source of income from fishing (**Table 12.6**). As mentioned above, this income can also be used to supplement the diet through the purchase of non-marine protein[46,47].

12.4.2 Plans to increase income earning opportunities based on fisheries and aquaculture

Predicting future employment in the tuna sector is difficult. Although plans for new canneries and loining plants in PNG and Solomon Islands have been announced, there is uncertainty over the future of tuna processing in American Samoa. However, as described in Section 12.2.2, there is potential to greatly increase direct and indirect employment based on tuna in PICTs that have suitable conditions for processing[17]. In short, if the ~ 700,000 tonnes of tuna caught from the EEZs of PICTs and shipped outside the region was processed in PICTs, another 40,000–50,000 jobs would be created. A key proviso here is that processing plants established in PICTs would need to be internationally competitive under the range of scenarios likely to be driven by trade agreements and other global factors[7]. With more vessels based in Pacific island ports, employment in service industries would also increase.

Few opportunities exist for increasing the number of livelihoods based on coastal demersal fisheries, and invertebrates targeted to produce export commodities, in most PICTs. Indeed, the hard decisions required to reduce fishing to restore the productivity of some coastal stocks (Section 12.2.4) would result in fewer jobs in the short to medium term. However, potential exists for more livelihoods to be created by the range of opportunities that exist for enhancing the production of coastal fisheries described in Section 12.2.4.

The plans to expand aquaculture in the region (Section 12.2.6) are also expected to create more opportunities to earn income, although it is still difficult to identify which commodities will drive these opportunities, or how the new jobs will be distributed among PICTs. Demand for fish in the rapidly growing urban centres of Melanesia should provide incentives for enterprises based on intense pond aquaculture. The relatively low cost of labour in Melanesia may also favour further development of pearl farming and seaweed culture. New jobs are also expected in the production of tropical marine ornamental products, although the limited size of the global market for these commodities is likely to provide relatively few additional opportunities to earn income.

12.5 Vulnerability of plans for economic development and government revenue

The substantial economic benefits derived from oceanic fisheries by PICTs, and the plans to sustain and expand those benefits, are expected to be affected by the projected changes in productivity of tuna described in Chapter 8. Here, we use the vulnerability framework outlined in Chapter 1, and applied widely to fisheries elsewhere[48–51] and throughout this book (Chapters 4–11), to identify the comparative vulnerability of future contributions of oceanic fisheries to economic development and government revenue. This framework uses the exposure of a national economy to changes in the availability of tuna and the sensitivity (dependence) of the economy to contributions from industrial fisheries to identify a potential impact, which can be offset to some extent by the adaptive capacity of the country or territory[52].

The analyses done in Chapter 8 provide estimates of the exposure of economic development and government revenue due to the effects of climate change on oceanic fisheries. The recent analysis of the contribution of tuna to the economies of PICTs[4], and the analyses in Section 12.2, allow the sensitivity of national economies to this exposure to be quantified. To assess the human and social capital that underpins the adaptive capacity of PICTs[53,54], we have relied heavily on the information collated for the region by the SPC Statistics for Development Programme[xii], and the World Bank. It is important to note, however, that the vulnerability assessment for economic development and government revenue only identifies the comparative vulnerability of PICTs; it does not identify projected losses or gains in real terms. This is done in Section 12.6 for the contributions of the surface tuna fishery.

12.5.1 Vulnerability of economies to changes in the surface tuna fishery

12.5.1.1 Calculating the vulnerability index

Assessing the vulnerability of national economies to the potential effects of climate change on the surface fishery depends mainly on the projections for the abundance of the skipjack tuna that dominate the catch[xiii]. We used the projected percentage changes in catches of skipjack tuna within the EEZ of a PICT, relative to the 20-year

xii www.spc.int/prism

xiii See Supplementary Table 12.1 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

average catch for 1980–2000 (Chapter 8) (**Table 12.7**), as the index of exposure of the surface fishery under the B1 and A2 scenarios in 2035, B1 in 2100 and A2 in 2100. Projected changes in catch are positive for all PICTs in 2035, however, depending on the location of the national EEZs, projected changes in catch are positive or negative by 2100 (**Table 12.7**). To construct an index of the sensitivity of a national economy to changes in projected catches by the surface fishery, we used the average percentage contributions of the fishery to GDP and government revenue (**Table 12.2**).

Potential impact (PI) was estimated by multiplying the exposure index (E) by the sensitivity index (S). Although a broad range of approaches are used to construct vulnerability indices[55], and additive approaches have been used in another broad assessment of the effects of climate change on global fisheries[50], we multiplied E x S to estimate potential impact. This recognised the vital importance of contributions to GDP and government revenue to the economies of some PICTs and suppressed high scores that would have occurred for PICTs where catches of skipjack are projected to increase substantially, but where they currently contribute little to the economy. Because the potential impact values were > 1 and varied widely, they were standardised and normalised to range from 0 to 1, with higher values representing greater potential impact.

To assess adaptive capacity, we combined four indices – health, education, governance and the size of the economy – on the assumption that PICTs with higher levels of human and economic development are in a better position to undertake planned adaptation. Health was estimated as a weighted combination of infant mortality rate (1/3) and life expectancy (2/3). Education was measured as the combination of the literacy rate for people up to 24 years of age (2/3) and the percentage of students enrolled in primary education (1/3). The World Bank governance index[56] was used to amalgamate six equally weighted aspects of governance: political stability, government effectiveness, regulatory quality, rule of law, voice and accountability, and corruption. To indicate the size of the economy and purchasing power parity we used GDP per person. The four adaptive capacity indices were standardised and normalised to range between 0 and 1, and then averaged to produce a composite adaptive capacity index (AC) (Appendix 12.1).

Vulnerability was calculated as PI multiplied by AC[xiv]. In PICTs with a surface fishery where the abundance of skipjack is projected to decrease, AC was inverted (1 - AC) so that the PICT with the greatest adaptive capacity had reduced vulnerability to lower catches of tuna. For PICTs where skipjack catches are projected to increase, the adaptive capacity index was retained as calculated to reflect the likelihood that the PICT with the greatest adaptive capacity would be more capable of maximising benefits from the increased resource.

xiv A limitation of the methods used to estimate vulnerability is that E changes over time because it is derived from the preliminary modelling summarised in **Table 12.7**, whereas S and AC are fixed at recent estimates.

Table 12.7 Projected percentage changes in catches of skipjack and bigeye tuna, relative to the 20-year average for 1980–2000, under the B1 and A2 emissions scenarios in 2035 and 2100, derived from the SEAPODYM model described in Chapter 8.

PICT	Skipjack			Bigeye		
	B1/A2 2035	B1 2100*	A2 2100	B1/A2 2035	B1 2100*	A2 2100
Melanesia						
Fiji	+26	+24	+33	+1	+1	-1
New Caledonia	+22	+19	+40	+1	+1	+6
PNG	+3	-11	-30	-4	-13	-28
Solomon Islands	+3	-5	-15	0	-3	-7
Vanuatu	+18	+15	+26	-3	-6	-10
Micronesia						
FSM	+14	+5	-16	-3	-11	-32
Guam	+16	+10	-8	-7	-13	-33
Kiribati	+37	+43	+24	-1	-5	-17
Marshall Islands	+24	+24	+10	-3	-10	-27
Nauru	+25	+20	-1	-1	-7	-19
CNMI	+23	+22	+13	0	-5	-23
Palau	+10	+2	-27	-4	-11	-45
Polynesia						
American Samoa	+41	+48	+58	-5	-8	-18
Cook Islands	+40	+50	+47	-3	-8	-15
French Polynesia	+41	+49	+77	-2	-8	-12
Niue	nea	nea	nea	-5	-8	-15
Pitcairn Islands	nea	nea	nea	-2	-4	-4
Samoa	+44	+49	+55	+1	+1	-4
Tokelau	+61	+69	+63	-3	-6	-16
Tonga	+47	+50	+58	-4	-5	-10
Tuvalu	+37	+41	+25	+3	+2	-6
Wallis and Futuna	+44	+49	+46	0	0	-7
Regional						
Total fishery	+19	+12	-7	+0.3	-9	-27
Western fishery**	+11	-0.2	-21	-2	-12	-34
Eastern fishery***	+37	+43	+27	+3	-4	-18

* Note that model simulations for A2 in 2050 have been used to approximate B1 in 2100; it is important to note, however, that while CO_2 emissions for these scenarios/times are similar, the multi-model mean of sea surface temperature is 0.18°C (±0.23) higher under B1 2100 than A2 2050; ** 15°N–20°S and 130°–170°E; *** 15°N–15°S and 170°E–150°W; nea = no estimate available.

Vulnerability (or potential benefit) was estimated for the B1 and A2 scenarios in 2035, in which exposure to changes in abundance of skipjack is similar (Chapter 8), for B1 in 2100, and for A2 in 2100.

We limited the vulnerability analyses to those PICTs where the surface fishery contributes at least 0.01% to either GDP and/or government revenue based on fishing operations alone (**Table 12.2**). Thus, American Samoa, Fiji, French Polynesia, Guam, Commonwealth of the Northern Mariana Islands (CNMI), New Caledonia, Niue, Pitcairn Islands and Wallis and Futuna were not considered, even though canneries make a great contribution to GDP in American Samoa (Section 12.2.1.1). Niue and Pitcairn Islands were not included either because no estimates of future changes in skipjack in their EEZs were available.

12.5.1.2 Comparative vulnerability of economies

Under the B1 and A2 scenario in 2035, the economy of Kiribati is projected to receive the greatest relative benefit from changes in the distribution and abundance of skipjack tuna (**Table 12.8**). Kiribati has a relatively high exposure to increased catches (**Table 12.7**) and is highly sensitive because access fees paid by DWFNs contribute > 40% of government revenue (**Table 12.2**). Although the potential benefit for Kiribati in 2035 is the highest for any PICT, it is somewhat constrained by a relatively low adaptive capacity[xv]. Projected changes in the surface fishery are also expected to have a relatively high positive effect on the small economy of Tokelau for similar reasons, although Tokelau has a higher exposure (**Table 12.7**) and a lower sensitivity (**Table 12.2**) than Kiribati. The economies of Nauru and Tuvalu are also likely to be quite well-placed to benefit from the increased abundance of skipjack in their EEZs by 2035, with more modest benefits flowing to Marshall Islands and FSM (**Table 12.7**).

The economies of PNG and Solomon Islands have very low positive scores relative to the PICTs listed above because (1) catches in their EEZs are projected to increase only slightly (**Table 12.7**); and, (2) despite the fact that catches are large, the tuna industry makes relatively low contributions to GDP and government revenue (**Table 12.2**). Although catches in the EEZs of Palau and Vanuatu are projected to increase by 10–20% by 2035, and those in Cook Islands, Samoa and Tonga are expected to increase by > 40%, the economies of these PICTs also have very low positive scores in relative terms due to the very limited contribution of the surface fishery to their economies (**Table 12.2**).

The relative scores for the economies of these PICTs are generally maintained under the B1 scenario in 2100 (equivalent to A2 in 2050), with the exception of PNG and Solomon Islands, which have negative scores because catches in their EEZs are projected to decrease compared to 1980–2000 levels, and FSM where benefits are projected to change from low to very low (**Table 12.8**). However, under the A2 scenario in 2100, the situation changes considerably. With the likelihood that skipjack will move further east and southeast into Polynesia (Chapter 8) (**Table 12.7**), the economies of FSM, Nauru and Palau are expected to join those of PNG and Solomon Islands in having increased vulnerability to negative economic impacts from the projected decreases in skipjack catches (**Table 12.7**). In the case of FSM and Solomon

xv See Supplementary Table 12.5 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

Islands, the vulnerability is rated as low, whereas it is still very low for PNG, Nauru and Palau. On the other hand, the positive effects for Tokelau increase from high to very high (**Table 12.8**).

Although American Samoa, Cook Islands, Fiji, French Polynesia and Vanuatu do not have significant surface fisheries (**Table 12.1**), and Wallis and Futuna does not have a surface fishery for tuna within its EEZs at all, these PICTs may be in an improved position in the future to develop domestic surface fisheries or to negotiate access fees with DWFNs if they so desire. These benefits are expected as a result of (1) the expected changes in distribution of skipjack tuna (Chapter 8); (2) the projected increases in catches from their EEZs (**Table 12.7**); and (3) the relatively high (or at least moderate) adaptive capacity of these PICTs (Appendix 12.1).

Table 12.8 Relative vulnerability (-) or benefit (+) for economies of Pacific Island countries and territories (PICTs) to projected changes in the surface fishery and longline fishery for tuna under the B1/A2 emissions scenarios for 2035, B1 for 2100 and A2 for 2100. Scores have been classified as very low (0.00–0.05), low (0.06–0.10), moderate (0.11–0.20), high (0.21–0.30) or very high (> 0.30). See Supplementary Tables 12.5–12.10 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) for the exposure, sensitivity, potential impact and adaptive capacity indices used to calculate the scores.

PICT	Surface fishery			Longline fishery		
	B1/A2 2035	B1 2100	A2 2100	B1/A2 2035	B1 2100	A2 2100
Melanesia						
Fiji*				- Very low	- Very low	- Very low
New Caledonia*				+ Very low	+ Very low	+ Very low
PNG	+ Very low	- Very low	- Very low	- Very low	- Very low	- Very low
Solomon Islands	+ Very low	- Very low	- Low	- Very low	- Very low	- Very low
Vanuatu	+ Very low	+ Very low	+ Very low	- Very low	- Very low	- Very low
Micronesia						
FSM	+ Low	+ Very low	- Low	- Moderate	- High	- Moderate
Kiribati	+ Very high	+ Very high	+ Very high	- Moderate	- Very high	- Very high
Marshall Islands	+ Low	+ Low	+ Low	- High	- Very high	- Very high
Nauru**	+ Moderate	+ Moderate	- Very low			
Palau	+ Very low	+ Very low	- Very low	- High	- Very high	- Very high
Polynesia						
American Samoa*				- Low	- Low	- Very low
Cook Islands	+ Very low	+ Very low	+ Very low	- Low	- Moderate	- Very low
French Polynesia				- Very low	- Very low	- Very low
Niue*				- Very high	- High	- Moderate
Samoa	+ Very low	+ Very low	+ Very low	- Very low	- Very low	- Very low
Tokelau**	+ High	+ High	+ Very high			
Tonga	+ Very low	+ Very low	+ Very low	- Very low	- Very low	- Very low
Tuvalu	+ Moderate	+ Moderate	+ Moderate	- Low	- Low	- Very low

* PICTs where the surface fishery contributes < 0.01% of gross domestic product (GDP); ** PICTs where the longline fishery contributes < 0.01% of GDP.

12.5.2 Vulnerability of economies to changes in the longline tuna fishery

Although the contributions to GDP and government revenue from the longline fishery are usually considerably lower than those from the surface fishery, they affect economies in a greater number of PICTs (Section 12.2.1.2). The vulnerabilities of economies to projected changes in the longline fishery were calculated in the same way described for the surface fishery. In the absence of projections for yellowfin tuna and albacore, we based the exposure index on the preliminary projections for changes in abundance of bigeye tuna within the EEZs of PICTs (Chapter 8) (**Table 12.7**). These projections are only a partial indicator of exposure because bigeye tuna made up only ~ 25% of the tuna caught by the longline fishery within the EEZs of PICTs in 2007, but 42% of the value[8]. The sensitivity of economies to changes in projected catches by the longline fishery was estimated as the average of the percentage contribution of the fishery to GDP in 2007[4], and the contribution to government revenue in 1993 or 2003[xvi], whichever was greatest.

Once again, we limited the vulnerability analyses to those PICTs where the longline fishery contributed > 0.01% to either GDP and/or government revenue based on fishing operations alone (**Table 12.2**); Guam, Nauru, CNMI, Pitcairn Islands, Tokelau and Wallis and Futuna were not included.

The projected decreases in catches of bigeye tuna under the B1 and A2 scenarios in 2035 (**Table 12.7**) indicate that most PICTs are likely to be vulnerable to loss of economic benefits from this component of the longline fishery. Several PICTs in Micronesia and Polynesia have relatively moderate, high or very high vulnerabilities to economic losses from reduced bigeye catches (**Table 12.8**). The most vulnerable PICTs are Niue, Palau and Marshall Islands because the longline fishery contributes ~ 2–4% of GDP[xvi].

As the projected catches of bigeye tuna decline further under the B1 scenario in 2100 (equivalent to A2 in 2050) (**Table 12.7**), the level of vulnerability increases for all PICTs in Micronesia, and for Cook Islands in Polynesia (**Table 12.8**). Kiribati has the most significant increase in relative vulnerability under this scenario (from moderate to very high) due to the high impact of reduced catches in its EEZ and its modest adaptive capacity. This is because Kiribati receives more government revenue from the longline fishery than other PICTs[xvi]. The relative vulnerability to losses of economic benefits of Marshall Islands and Palau also increases to very high due to the rapid increase in potential impact[xvii] as a result of the large projected decreases in catches of bigeye tuna from the longline fishery in their EEZs under the B1 emissions scenario in 2100 (**Table 12.7**). The vulnerability of FSM increases from moderate to high for similar reasons. These patterns of vulnerability among PICTs are largely maintained under the A2 scenario in 2100 (**Table 12.8**), although the great decrease in projected catch of bigeye tuna for Palau (**Table 12.7**) suppresses the relative vulnerabilities of some of the PICTs compared to the B1 emissions scenario in 2100.

xvi See Supplementary Table 12.4 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

xvii See Supplementary Tables 12.8 and 12.9 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

Modelling needs to be done for yellowfin tuna and albacore, the two other species of tuna taken by the longline fishery, to determine whether the vulnerabilities of economies to projected decreases in the catches of bigeye tuna are representative of this fishery in general. Such modelling is needed to determine whether some of the projected benefits from the surface fishery for PICTs in Micronesia and Polynesia as skipjack tuna move east could be undermined by reduced catches from longlining. Any effects of this type may be relatively minor, however, because the potential economic benefits for PICTs from establishment of a surface fishery in their EEZs might reasonably be expected to outweigh losses from reduced longlining catches.

12.6 Potential effects on economic development and government revenue from projected changes to the surface tuna fishery

To assess the potential effects of projected changes to the surface fishery on the economies of PICTs, we estimated the lower and upper bounds of projected contributions to GDP and government revenue under the B1 and A2 scenarios in 2035, B1 in 2100 and A2 in 2100. The range was based on the variation in estimates of GDP and government revenue derived from the surface tuna fishery between 1999 and 2008. The estimates were also based on the following assumptions.

- Projected catches of skipjack tuna are a good indicator of the effects of changes to the surface fishery on national economies because landings of skipjack dominate this fishery (Section 12.2.1.1).
- Variations in catch will have similar impacts both on GDP, and on government revenues. Thus, if the contribution of the surface fishery is estimated to be 5% of GDP, and catch is projected to rise by 10%, then the increased contribution to GDP due to the greater catch is estimated to be 0.5% of GDP.
- Tuna prices, GDP, levels of taxation, and the value-added component of purse-seine and pole-and-line fishing operations, remain constant, relative to 1999–2008 levels. These assumptions are common in other future economic vulnerability analyses[57].
- The balance between catches by locally-based fleets (which contribute to GDP) and DWFNs (which do not) remain constant.
- Fishing effort remains constant. We recognise that this is unlikely because as catch per unit effort (CPUE) in an area changes, the relative profitability of fishing also changes. As a result, fishing effort increases in areas where CPUE improves, and decreases where CPUE declines. This means that the impacts estimated in this analysis are likely to be amplified. For example, if catches within an EEZ fall by 30% under current effort levels, further significant falls in fishing effort would be expected as vessels move to areas where CPUE is greater, causing declines in catch much greater than 30% within the EEZ. Without coupled biophysical and fleet dynamics models, we cannot include such complexity in our assessment.

Our analysis is restricted to PICTs where the average contribution of the surface fishery to GDP or government revenue was > 1% over the period 1999–2008, or where large quantities of skipjack tuna were transshipped or processed. These PICTs are: PNG and Solomon Islands, where tuna are caught and processed and/or transshipped; FSM, Kiribati, Marshall Islands, Nauru, Palau, Tuvalu and Tokelau, where tuna is caught within the EEZ; and American Samoa where there are significant processing operations (**Table 12.2**). The estimated impacts are based on the preliminary modelling of catch variations in the EEZ of each PICT (**Table 12.7**) (Chapter 8). However, because the post-harvest processing sector in American Samoa is supplied by fish caught throughout the fishery, the impacts on American Samoa are based on the projected catch variations for the fishery as a whole (**Table 12.7**).

The projected increases in catches of skipjack tuna by 2035 show that landings are expected to rise by ~ 20% across the fishery, driven by strong increases (> 35%) in catch in the eastern part of the region and more modest increases (~ 10%) in catches in the west (**Table 12.7**). The expected improvements in catch lead to projected increases in GDP and government revenue by 2035, particularly for those PICTs in the east (**Table 12.9**). The most significant projected increases to GDP associated with the projected changes in catch are for American Samoa (3–6%) and Marshall Islands (2–6%). The greatest expected increases in government revenue are for Kiribati (11–18%), Tuvalu (4–9%), Tokelau (1–9%) and Nauru (2–6%) (**Table 12.9**).

Under the B1 scenario in 2100 (equivalent to A2 in 2050), the catch of skipjack tuna is projected to rise by 12% overall, driven by expected increases in catch in the eastern region of the fishery of > 40%, with a marginal decline in projected catches in the western region (**Table 12.7**). For PICTs in Micronesia and Polynesia, the general level of benefits projected for 2035 are expected to continue in 2100 (**Table 12.9**). On the other hand, projected decreases in catch of 11% in PNG and 5% in Solomon Islands by 2100 under the B1 scenario (**Table 12.7**) are expected to lead to declines in GDP and government revenues. However, due to the relatively low importance of the surface fishery to the larger economies of these PICTs, GDP is estimated to decline by only 0.1–0.4% in both countries. Government revenues are also expected to fall by only 0.1% in PNG and 0.3% in Solomon Islands (**Table 12.9**).

By 2100 under the A2 scenario, catches of skipjack tuna are projected to fall for the fishery as a whole by around 7% because the modest projected increases in the east of the region (27%) are more than offset by the expected decline of 21% in the larger component of the fishery in the west (**Table 12.7**). The projected 30% decline in catches of skipjack tuna in the EEZ of PNG is particularly significant, although it is estimated to result in a reduction of only up to 1.2% in GDP, and 0.2% in government revenue, due to the large size of the economy in PNG. The projected declines in catches from Solomon Islands and FSM of ~ 15% are also expected to cause reductions of about 0.8–1% in GDP, and ~ 1–2% in government revenue in both countries. The catch in Nauru, and consequentially government revenue, is expected to fall only marginally.

Marshall Islands, Kiribati and Tuvalu are projected to continue to receive increased economic benefits under the A2 scenario in 2100, albeit at lower levels than for B1 and A2 in 2035, or under the B1 scenario in 2100 (**Table 12.9**).

Table 12.9 Changes in percentage contributions of oceanic fisheries to GDP and government revenues in Pacific Island countries and territories (PICTs), relative to 1999–2008, resulting from projected alterations in the catch of skipjack tuna in 2035 and 2100 under B1 and A2 emissions scenarios. Lower (L) and upper (U) limits for these projections are estimated for each scenario, and shown for the period 1998–2008. Only PICTs where industrial fishing or processing contributes > 1% of GDP or government revenue are included.

PICT	Change to GDP (%)								Change to government revenue (%)							
	1999–2008 (%)		B1/A2 2035		B1* 2100		A2 2100		1999–2008 (%)		B1/A2 2035		B1* 2100		A2 2100	
	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U
Melanesia																
PNG	1.5	4	0	+0.1	-0.2	-0.4	-0.4	-1.2	0.2	0.8	0	0	0	-0.1	-0.1	-0.2
Solomon Islands	2	5	+0.1	+0.2	-0.1	-0.3	-0.3	-0.8	0.2	5	0	+0.2	0	-0.3	0	-0.8
Micronesia																
FSM	1.5	5	0	+1	0	0	0	-1	6	12	+1	+2	0	+1	-1	-2
Kiribati									30	50	+11	+18	+13	+21	+7	+12
Marshall Islands	10	25	+2	+6	+2	+6	+1	+2	2	5	0	+1	0	+1	0	0
Nauru									10	25	+2	+6	+2	+5	0	0
Palau									2.5	3.2	+0.2	+0.3	0	+0.1	-0.7	-0.9
Polynesia																
American Samoa	20	25	+3	+6	+2	+4	-1	-2	5	20	+1	+4	+1	+2	0	-1
Tokelau									2	15	+1	+9	+1	+10	+1	+9
Tuvalu									10	25	+4	+9	+4	+10	+2	+6

* Approximates the A2 emissions scenario in 2050 (**Table 12.7**).

The expected outcomes for American Samoa are mixed. Projected increases in overall catches of skipjack tuna to 2035, and under the B1 scenario in 2100, may have a positive impact. Conversely, catch declines under the A2 scenario in 2100 may have a negative effect on the economy in American Samoa.

We emphasise that the analyses presented here are preliminary, and based on some simplistic assumptions – the estimates provide only an indication of the direction and magnitude of possible economic impacts and need to be improved by matching the baselines for projected catches (1980–2000) with the baselines for the contributions to GDP and government revenue (1999–2008). More advanced modelling of future catches of skipjack tuna needs to be done, incorporating outputs from the new generation of global physical climate models linked to biological parameters (e.g. prey for tuna) and to fleet dynamics models (e.g. fishing effort changes). Modelling the effects of climate change projections on yellowfin tuna also needs to be integrated with the modelling for skipjack tuna to provide a more complete picture for the surface fishery.

12.7 Vulnerability of plans for using fish for food security

12.7.1 Differences in capacity to provide fish among PICTs

The amount of fish needed to assist PICTs to achieve food security over the coming decades has been publicised widely[2,3,7,34,40,43]. As outlined in Section 12.3.2, the quantities of fish required, and the plans to supply them, have been based on (1) identifying the consumption of fish per person needed for good nutrition or the traditionally higher levels of fish consumption typical of many PICTs; (2) forecasting the amount of fish needed by the growing populations of the region; (3) identifying the fish likely to be available to meet the projected needs; and (4) assessing how best to increase access to additional fish where required.

The amount of fish needed for food security by each PICT over the next couple of decades due to increases in population is well understood[3] (**Table 12.5**). Identifying where the 35 kg of fish per person per year recommended for good nutrition[40] will come from is not as straightforward. However, it is reasonable to assume that much of the fish used for food will continue to be supplied by coastal fisheries[4] (Chapter 9), and from freshwater fisheries in some parts of PNG, Fiji and Solomon Islands (Chapter 10). This is because these resources are on the 'doorstep' of rural communities, and within easy access for subsistence fishers.

In the absence of detailed information on the sustainable production of coastal fisheries throughout the region (Chapter 9), we have used three sets of data to estimate the quantities of fish likely to be available per person in each PICT for food security until the end of the 21st century. These data sets are (1) the area of coral reef in km^2 (Chapter 5); (2) a median estimate of sustainable fisheries production from coral reef habitats of 3 tonnes per km^2 per year[21] (Chapter 9); and (3) the predicted future population of each PICT (see Appendix 12.2 for details of how datasets (1) and (2) were used to estimate sustainable fisheries production and how they were modified for PICTs with freshwater fisheries; and Chapter 1 for predicted populations of PICTs in 2035).

In recognition of the fact that there is considerable variation in the productivity of coastal fisheries throughout the region (Chapter 9), we have also assessed the quantities of fish expected to be available per person in the future where the status of fisheries resources is poor to medium and fishing pressure is high, and where fisheries resources is medium to good and fishing pressure is low[21,22] (Chapter 9). Sustainable fish production in these situations was assumed to be 1 tonne and 5 tonnes per km^2 of coral reef per year, respectively.

When the capacity of PICTs to supply their populations with the recommended 35 kg of fish per person per year for the remainder of the 21st century is estimated as described above, PICTs fall into three groups[xviii].

xviii Note that the classification of PICTs here differs slightly to that of Bell et al. (2009)[4] because more information is now available on the area of coral reef in each PICT (Chapter 5).

- **Group 1** (Cook Islands, Marshall Islands, New Caledonia, Palau, Pitcairn Islands and Tokelau), where coastal fisheries are expected to meet the increased demand for fish for the foreseeable future. Planning the use of fish for food security in this group of PICTs relies mainly on good management of coral reefs so that they can continue to yield their normal harvests (Chapter 13), and ensuring that excessive catches are not made for local tourism or export.
- **Group 2** (FSM, French Polynesia, Kiribati, Niue, Tonga, Tuvalu and Wallis and Futuna), where the area of coral reef should be able to produce the fish needed in the future, but where it will be difficult to distribute the potential harvests to urban centres because of the great distances between the main population centres and the islands, atolls and reefs, where the fish occur. Regular access to the fish needed by the growing urban populations in these PICTs will depend not only on good management of coral reefs, but also on (1) installation of low-cost FADs anchored inshore to assist subsistence and artisanal fishers catch tuna; (2) improved access to tuna and bycatch caught by industrial fisheries; and (3) development of fisheries for small pelagic fish (Sections 12.2.4 and 12.3.2).
- **Group 3** (American Samoa, Fiji, Guam, Nauru, CNMI, PNG, Samoa, Solomon Islands and Vanuatu), where coral reefs and other coastal habitats do not have the potential to produce the fish needed for good nutrition of their populations. In these PICTs, the plans to supply the fish required emphasise the need to manage coastal fisheries and fish habitats as well as possible to minimise the gap between the fish needed for food security and the fish available from coral reefs and other coastal habitats[40]. These plans also depend heavily on the interventions to increase access to tuna described above, particularly facilitating the distribution of low-value fish and bycatch from industrial fleets and installing anchored inshore FADs to assist subsistence and artisanal fishers in rural areas to catch tuna. However, development of small pond aquaculture where there is adequate fresh water[3,45] (Chapter 11), and scaling-up fisheries for small pelagic fish (Chapter 9), also have potential to make substantial contributions to the fish required at the local level, and modest contributions nationally.

  In some of the more economically developed PICTs in Group 3 (e.g. American Samoa, Guam and CNMI), purchases of local and imported canned tuna can also provide much of the fish required. The relatively high GDP per person in these three PICTs (Appendix 12.1) also means that many people there will have the ability to purchase other sources of animal protein and may not always need 35 kg of fish per year for good nutrition. Nevertheless, all PICTs in Group 3 have been analysed in the same way.

To determine whether the plans described above could be derailed by climate change, we estimated the effects of the projected changes in coastal fisheries production (and freshwater fisheries production where relevant) under the B1 and A2 emissions scenarios on future availability of fish per person, over and above the effects of population growth (see Appendix 12.2 for the methods involved).

Due to the strong interest in this issue in the region[44,47,58,59] we analysed the effects of population growth and climate change on the supply of fish for food security in 2035, 2050 and 2100 to provide assessments for the near, mid and long term. Projections are provided for the B1 and A2 emissions scenarios in 2035 and for B1 in 2100 and A2 in 2100, but only for A2 in 2050, where we have used the projected effects for B1 in 2100 as a surrogate for A2 in 2050 (Chapter 1). The predicted populations of PICTs in 2035 are given in Chapter 1, and for 2050 and 2100 in Appendix 12.3. The methods used to make the predictions for 2100 are given in Appendix 12.4.

12.7.2 Vulnerability of Group 1

Based on access to coastal fisheries resources alone, availability of fish per person is not at risk of falling below the recommended 35 kg per year or the higher levels of traditional fish consumption for PICTs in Group 1, even under the A2 scenario in 2100 (Table 12.10). This is due to the large areas of coral reef relative to population size in these countries and territories, and the prediction that population growth will be stagnant or negative due to emigration in several of these PICTs.

Table 12.10 Estimates of fish available per person for the B1/A2 emissions scenarios in 2035, A2 in 2050, and B1 and A2 in 2100 for Pacific Island countries and territories (PICTs) in Group 1 (Section 12.7.1). These estimates assume sustainable fisheries production of 3 tonnes per km² of coral reef per year. See Appendix 12.2 for a description of methods and Supplementary Tables 12.11–12.14 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) for details of calculations.

PICT*	Reef area (km²)**	Estimated potential fish yield per km² per year (tonnes)	Population***			Fish available per person per year (kg)[a]			
			2035	2050	2100	B1/A2 2035	A2 2050	B1 2100	A2 2100
Melanesia									
New Caledonia	35,925	107,775	322,500	343,000	372,000	326	268	245	215
Micronesia									
Marshall Islands	13,930	41,790	62,700	61,200	61,000	644	566	558	484
Palau	2496	7488	22,700	22,500	22,000	320	283	279	250
Polynesia									
Cook Islands	667	2000	16,900	16,900	16,000	115	101	107	92
Tokelau	204	612	12,800	1150	1150	495	451	451	388

* Pitcairn Islands not included but estimates of fish available per person per year exceed 900 kg for all scenarios; ** derived from Chapter 5; *** source: SPC Statistics for Development Programme; a = includes invertebrates.

In the unlikely event that sustainable production of fisheries from coral reefs in PICTs in Group 1 averages only 1 tonne per km² per year, the availability of fish per person per year, even under the A2 scenario in 2100, is still estimated to be more than twice the recommended level for good nutrition (Table 12.11). The exception is Cook Islands, where 31 kg of fish per person per year would be available.

Tuna are also caught by small-scale subsistence and artisanal fisheries in PICTs in Group 1 (Chapter 9) but are not included in the analyses because they do not depend directly on coastal habitats (Chapters 4 and 8). However, the ability of PICTs in Group 1 to provide sufficient fish for food security is strengthened further by the projections that their access to tuna is expected to increase substantially under a warmer climate (**Table 12.7**). The exception is Palau in 2100 under the A2 scenario, where catches of tuna are projected to decrease by > 25%.

Table 12.11 Relative effects of population growth (P) and climate change emissions scenarios (B1, A2) on future availability of fish in the three groups of Pacific Island countries and territories (PICTs) (Section 12.7.1). Values are estimated averages of fish available per person per year (kg) for all PICTs in the group due to population growth alone, and for the combined effects of population growth and climate change under the B1/A2 emissions scenarios in 2035, A2 in 2050, and B1 and A2 in 2100. Estimates are for three levels of fisheries production: 3 tonnes per km^2 of coral reef per year (considered to be most likely), 1 tonne per km^2 per year (to represent reefs where resource status is poor to medium and fishing pressure is high), and 5 tonnes per km^2 per year (for reefs where the status of resources is medium to good and fishing pressure is low). Note that Group 3 includes contributions from freshwater fish, which are held constant.

Group	Tonnes of fish per km^2 per year	Availability of fish per person per year (kg)						
		2035		2050		2100		
		P	B1/A2	P	A2	P	B1	A2
1*	1	130	125	130	110	130	110	95
	3	390	375	390	330	390	330	285
	5	650	625	650	550	650	550	475
2	1	90	86	85	71	75	62	54
	3	270	258	255	213	225	186	162
	5	450	430	425	355	375	310	270
3	1	5.7	5.6	5.0	4.7	3.9	3.4	3.1
	3	15.2	14.8	13.7	11.8	10.5	9.0	7.9
	5	24.8	24.1	22.2	19.0	17.1	14.7	12.8

* Average does not include Pitcairn Islands.

12.7.3 Vulnerability of Group 2

The problems encountered by most PICTs that currently have the capacity to produce the fish needed for food security, but encounter difficulties in distributing it to population centres, are not generally expected to be exacerbated by climate change. Even under the A2 scenario, most PICTs in Group 2 are still expected to have the potential to produce enough fish to meet traditional levels of fish consumption (**Table 12.12**).

The exception is Kiribati under all scenarios (**Table 12.12**). In the unlikely event that all future production of reef-associated fish could be distributed effectively from remote islands to the main population centres, reefs in Kiribati are estimated to produce only

65 kg per person per year in 2050 under the A2 scenario, 50 kg per person under B1 in 2100 and 42 kg per person under A2 in 2100. Although such production supplies the recommended 35 kg of fish per person per year it is insufficient to maintain the traditionally high levels of fish consumption in Kiribati[3]. In French Polynesia, the potential annual reef fish production available per person is estimated to be 85 kg per person under A2 in 2100, which would be sufficient to maintain the traditionally high levels of consumption (Table 12.5) provided this fish can be distributed effectively.

Table 12.12 Estimates of fish available per person for the B1/A2 emissions scenarios in 2035, A2 in 2050, and B1 and A2 in 2100 for Pacific Island countries and territories (PICTs) in Group 2 (Section 12.7.1). These estimates assume sustainable fisheries production of 3 tonnes per km² of coral reef per year. See Appendix 12.2 for a description of methods and Supplementary Tables 12.15–12.18 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) for details of calculations.

PICT	Reef area (km²)*	Estimated potential fish yield per km² per year (tonnes)	Population**			Fish available per person per year (kg)[a]			
			2035	2050	2100	B1/A2 2035	A2 2050	B1 2100	A2 2100
Micronesia									
FSM	15,074	45,222	105,300	109,300	109,300	418	352	352	307
Kiribati	4320	12,960	144,600	163,300	211,300	86[b]	65[b]	50[b]	42[b]
Polynesia									
French Polynesia	15,126	45,378	330,800	348,800	378,900	131	109	100	85
Niue	56	168	1200	1300	1300	125	114	114	104
Tonga	5811	17,433	115,000	123,000	146,900	145	116	97	81
Tuvalu	3175	9525	12,800	13,900	18,500	711	570	428	362
Wallis and Futuna	932	2796	13,600	13,600	13,600	197	171	172	145

* Derived from Chapter 5; ** source: SPC Statistics for Development Programme (see also Appendix 12.3); a = includes invertebrates; b = PICTs where availability of reef-associated fish per person is less than current rates of traditional fish consumption.

If reef-dependent fisheries in PICTs in Group 2 turn out to be less productive than the estimated median value for coral reefs in general, and yield only 1 tonne of fish per km² per year, average annual fish production would still be more than the recommended level of 35 kg per person per year under all climate change scenarios (Table 12.11). Notwithstanding the difficulties in distributing the potential production, this analysis masks the fact that access to fish in Kiribati would fall below the recommended level of 35 kg per person per year for all scenarios. Similar problems would also occur in French Polynesia and Tonga in 2100. On the other hand, if production from reef-dependent fisheries is higher than the median estimate, at 5 tonnes per km² per year, the potential availability of fish per person for PICTs in Group 2 far exceeds traditional levels of fish consumption, except in Kiribati under A2 in 2100.

The good news for most PICTs in Group 2 is that the plans they need to make to provide better access to tuna to fill any shortfall in supply of reef-associated fish, due to difficulties in distribution of catches (Section 12.7.1), are expected to be enhanced by the projected changes in the distribution and abundance of tuna (Chapter 8). This is especially important for Kiribati and French Polynesia, where catches of skipjack tuna are projected to increase by > 35% in 2035 (**Table 12.7**). FSM is the exception in 2100 under the A2 scenario, when abundances of skipjack tuna are projected to decline by > 25% (**Table 12.7**).

12.7.4 Vulnerability of Group 3

PICTs in Group 3 are in a very different situation to those in Groups 1 and 2. Based on median estimated production of reef-associated fish and invertebrates of 3 tonnes per km^2 per year[21], and current freshwater fish production[4] (Chapter 10), many of the PICTs in Group 3 were already facing a very large gap in the fish needed for good nutrition of their populations in 2010 (**Table 12.13**). Fiji and Solomon Islands are the exceptions – their coastal and freshwater fisheries are currently likely to be producing > 35 kg of fish per person per year. Coastal fisheries in Samoa are estimated to produce close to the recommended quantities of fish. On the other hand, reefs in Nauru and Guam only provide a small fraction of the fish required. The gap in PNG only applies to coastal communities and those living close to freshwater habitats – the gap is far greater for the very large inland populations which have little access to fish[3].

Due to the complexity of the situation for PICTs in Group 3, we present their vulnerability to shortages of fish due to population growth and climate change separately, rather than together as done for Groups 1 and 2 above.

12.7.4.1 Vulnerability to shortages of fish due to population growth alone

The large predicted growth in the populations of PNG, Solomon Islands and Vanuatu causes the projected availability of fish per person to decline substantially in 2035, 2050 and 2100 (**Table 12.13**). The changes in Solomon Islands are particularly dramatic – the estimated fish surplus of 15 kg per person per year in 2010 changes to a shortfall of 7 kg in 2035, 13 kg in 2050 and 21 kg in 2100. The gap also continues to widen for all PICTs in Group 3 over time, although it does not increase substantially for Guam, Nauru and CNMI because the shortfalls in fish required for good nutrition based on coastal fisheries production of 3 tonnes per km^2 per year in these four PICTs are already very large (**Table 12.13**).

Even if sustainable fisheries production from coral reefs is considered to be 5 tonnes per km^2 per year, there would still be an average shortfall in the recommended access to 35 kg of fish per person per year of 10 kg in 2035, 13 kg in 2050 and 18 kg in 2100 for PICTs in Group 3 (**Table 12.11**). The exceptions are Fiji, Samoa and Solomon Islands, where such rates of production would meet the recommended supply of fish for good nutrition in Fiji and Samoa until 2100, and in Solomon Islands until 2050. On the other hand, if sustainable production is only 1 tonne per km^2 per year, the average gap to be filled between the fish needed for good nutrition and the fish available is projected to be ~ 30–32 kg from 2035 onwards, and ranges from 20–35 kg per person per year for all PICTs in Group 3.

Table 12.13 Gap between the recommended fish consumption of 35 kg per person per year, and the estimated annual supply of fish per person from coastal (reef-associated) and freshwater fisheries in 2010, 2035, 2050 and 2100 for each of the Pacific Island countries and territories (PICTs) in Group 3 (Section 12.7.1). Note that these projected gaps do not incorporate the impacts of climate change, and are based on sustainable fisheries production of 3 tonnes per km^2 of coral reef per year. See Appendix 12.5 for estimates of reef area, fish production and predicted populations of PICTs in 2010, 2035, 2050 and 2100 used to calculate total fish available per person and the gap in fish needed per person.

PICT	Total fish available per person per year (kg)				Gap in fish needed for good nutrition per person per year (kg)			
	2010	2035	2050	2100	2010	2035	2050	2100
Melanesia								
Fiji	40	35	32	26	+(5)	0	3	9
PNG	12	8	6	4	23	27	29	31
Solomon Islands	50	28	23	14	+(15)	7	12	21
Vanuatu	16	10	8	6	19	25	27	29
Micronesia								
Guam	4	3	3	2	31	32	32	33
Nauru	2	1	1	1	33	34	34	34
CNMI	12	10	9	9	23	25	26	26
Polynesia								
American Samoa	17	13	11	8	18	22	24	27
Samoa	33	30	29	25	2	5	6	10

+ Indicates that there is no gap (surplus fish).

12.7.4.2 Increased vulnerability due to climate change

Climate change is expected to have relatively minor effects on availability of fish per person compared to those due to population growth for PICTs in Group 3. When the projected effects of the B1 and A2 emissions scenarios in 2035, A2 in 2050, B1 in 2100 and A2 in 2100 on the abundances of coastal and freshwater fish (Chapters 9 and 10) are added to the effects of population growth, the access to fish per person decreases by only 1–2 kg under all scenarios for most PICTs in Group 3. There are two main reasons for this. First, a very large gap already exists between the amount of fish needed for good nutrition and the estimated sustainable harvests from the areas of coral reef and associated coastal habitats in many of these PICTs (**Table 12.13**). Second, the effects of population growth on availability of reef-associated fish per person are profound (**Table 12.13**), leaving little scope for climate change to increase the gap further. Varying the estimates of sustainable coastal fisheries production from 1 tonne to 5 tonnes per km^2 does not alter this basic pattern substantially (**Table 12.11**).

The exceptions are Fiji, Solomon Islands and Samoa[xix]. The effects of climate change on the supply of coastal fish, over and above those caused by population growth, for Fiji and Solomon Islands are shown in **Figure 12.4**. In both countries, the additional gap in the fish required due to climate change is expected to be relatively small initially, and becomes more noticeable in 2050 and 2100.

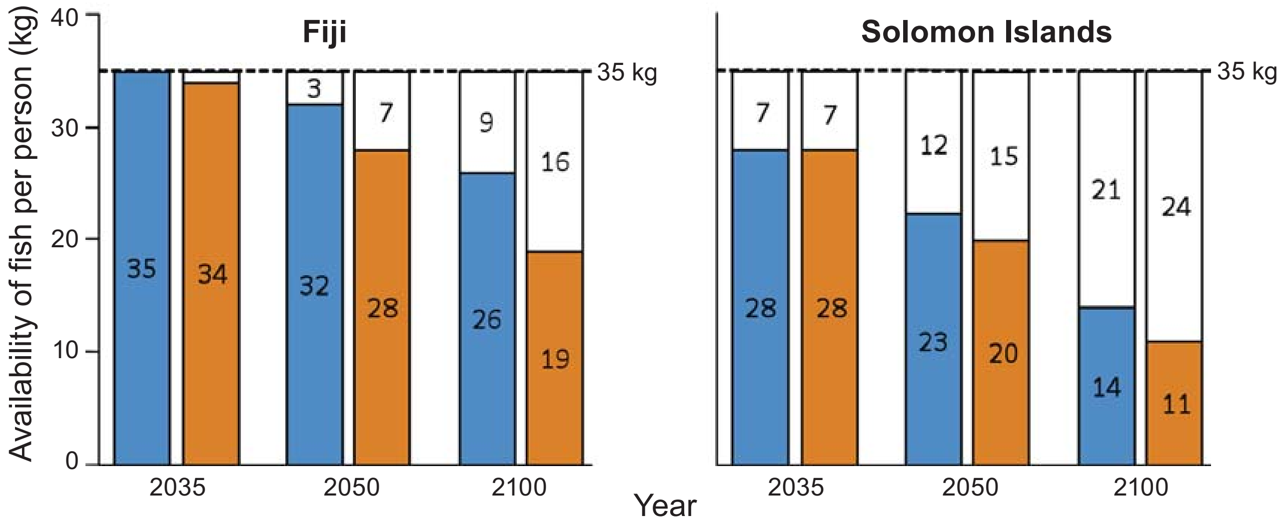


Figure 12.4 Relative effects of population growth and the A2 emissions scenario on the gap between recommended annual fish consumption of 35 kg per person, and the estimated annual supply of fish from coastal and freshwater fisheries in 2035, 2050 and 2100 for Fiji and Solomon Islands; ■ = availability of fish per person due to the effects of population growth alone; ■ = availability of fish per person remaining after the combined effects of population growth and climate change. See Appendix 12.2 and Supplementary Tables 12.19–12.22 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) for methods used to estimate the additional gap due to climate change.

12.7.4.3 Relative vulnerability of PICTs in Group 3

Estimating how climate change is likely to add to the effects of population growth on the availability of fish per person is not the only way to assess the vulnerability of PICTs in Group 3 to shortages of fish for food security. Because these PICTs vary in their traditional dependence on fish, and their capacity to adapt to changing conditions, we have also applied the vulnerability framework described in Chapter 1 and Section 12.5. This analysis assesses the relative vulnerability of PICTs in Group 3 to the use of fish for food in the face of population growth and climate change (in the absence of the plans to increase access to fish mentioned in Section 12.7.1).

We estimated exposure to shortages of fish in each PICT for the B1 and A2 scenarios in 2035, A2 in 2050, and B1 and A2 in 2100, using an index based on the availability per person (kg) of (1) demersal fish, non-tuna nearshore pelagic fish and shallow subtidal and intertidal invertebrates in proportion to their contributions to the estimated production of 3 tonnes per km^2 per year, and (2) freshwater fish based on

xix Compare Supplementary Tables 12.19–12.22 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) with **Table 12.13**.

current national catches[4,xx]. Although tuna contribute to coastal fisheries in several PICTs in Group 3 (Chapter 9), we have not included them in the exposure index for the reasons outlined in Appendix 12.2. The availability of all reef-associated fish and invertebrates, and freshwater fish, was modified by the projected changes to their production under each scenario (Appendix 12.2). The resulting total availability of fish per person was then deducted from the 35 kg per person required for good nutrition to estimate the exposure (E) of each PICT.

Sensitivity (S) was estimated as the recommended level of fish consumption for good nutrition (35 kg per person per year)[3,40], or higher national levels of consumption where these occur[3,4,60]. Potential impact (PI) was estimated as E x S, and then standardised and normalised.

The capacity of PICTs in Group 3 to adapt to shortages in the supply of fish was calculated differently to the adaptive capacity index used to assess the vulnerability of economic development and government revenue (Appendix 12.1). This was done because, in the absence of plans to provide greater access to other sources of fish, purchasing power plays a greater role in allowing individuals to acquire fish. Therefore, the adaptive capacity index for food security (AC) was estimated by weighting the values for the size of the economy (purchasing power) by 0.5, and the indices for health, education and governance by 0.167 (Appendix 12.1).

Vulnerability was estimated by multiplying PI x (1 - AC), so that the potential impact on PICTs in Group 3 with the greatest adaptive capacity was reduced relative to PICTs with poor adaptive capacity.

In 2035 under the B1 and A2 scenarios, Fiji has a very low vulnerability (**Table 12.14**) to shortages of fish because estimated harvests are largely projected to provide 35 kg of fish per person per year for the increased population. Solomon Islands has a low vulnerability because the shortfall of 7 kg of reef-associated and freshwater fish per person per year projected to occur there is much lower than for most other PICTs except Samoa, which has a moderate vulnerability due to its traditionally high fish consumption (**Table 12.5**). Guam also has a moderate vulnerability but for a different reason – the potential impact of the great shortages of reef-associated fish per person expected to occur there is reduced by substantial national adaptive capacity. The vulnerability of CNMI is high rather than very high for similar reasons. American Samoa, Nauru, PNG and Vanuatu have a very high vulnerability to shortages in the recommended, or traditional, levels of fish consumption because of the projected limitations to the amount of fish available per person and weak adaptive capacity (**Table 12.14**).

As indicated in Section 12.7.4, the aspirations to provide 35 kg of fish per person for the large inland communities in PNG are unrealistic. PNG would be expected to have a somewhat reduced, but still high, vulnerability to shortages of fish in the future if

xx See Supplementary Tables 12.23–12.26 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

the present-day rate of fish consumption per person (**Table 12.5**) was used to assess vulnerability.

These general patterns of vulnerability are expected to be maintained in all PICTs in Group 3 under A2 in 2050, and B1 and A2 in 2100, except Samoa, Guam, Vanuatu and Solomon Islands (**Table 12.14**). The vulnerability of Samoa increases from moderate in 2050 to high in 2100 due to substantial decreases in access to fish per person. A similar trend also occurs in American Samoa. The relatively rapid increases in vulnerability scores in Samoa, and in America Samoa[xxi], reduces the relative vulnerability of Guam, which decreases from moderate in 2050 to low in 2100, and Vanuatu, which declines from very high in 2050 to high in 2100. The relative vulnerability of Solomon Islands increases from low in 2035 to moderate to high in 2050 and 2100 (**Table 12.14**).

Table 12.14 Relative vulnerability scores of Pacific Island countries and territories (PICTs) in Group 3 to the availability of coastal (reef-associated) and freshwater fish for food security under the B1/A2 emissions scenarios for 2035, A2 for 2050, and B1 and A2 in 2100. Scores have been classified as very low (0.00–0.05), low (0.06–0.10), moderate (0.11–0.20), high (0.21–0.30) or very high (> 0.30). See Supplementary Tables 12.23–12.26 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) for exact vulnerability scores and the values of indices for exposure, sensitivity, potential impact and adaptive capacity used to calculate the scores.

PICT	Emissions scenarios			
	B1/A2 2035	A2 2050	B1 2100	A2 2100
Melanesia				
Fiji	Very low	Very Low	Very Low	Very Low
PNG	Very High	Very High	Very High	Very High
Solomon Islands	Low	Moderate	High	Moderate
Vanuatu	Very High	Very High	High	High
Micronesia				
Guam	Moderate	Moderate	Low	Low
Nauru	Very high	Very high	Very high	Very high
CNMI	High	High	High	High
Polynesia				
American Samoa	Very high	Very high	Very high	Very high
Samoa	Moderate	Moderate	High	High

12.7.4.4 Vulnerability of plans to increase access to fish in Group 3

The reality is that although reef-associated fish and invertebrates have long been the main source of food for PICTs, tuna have also provided a significant amount of the fish captured by coastal fisheries for local consumption (Chapter 9). Considering the very large gap to be filled between the amount of fish needed for good nutrition and the reduced quantities of reef-associated and freshwater fish available per person due to the combined effects of population growth and climate change (Section 12.7.4.2), PICTs in Group 3 will need to depend heavily on the plans to use tuna to meet the shortfall in supply of fish for food security (Section 12.7.1).

xxi See Supplementary Tables 12.23–12.26 (www.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf).

Potential contributions from pond aquaculture could help diversify local fish production but will be minor compared to the contributions that tuna can make at the national level. Assuming there is adequate investment in farming systems and progressive development, pond aquaculture has the potential to supply up to 1 kg of fish per person at the national level by 2035, 2 kg by 2050 and 4 kg by 2100 in PICTs in Group 3, except American Samoa, Guam, Nauru and CNMI where areas for construction of ponds are limited (Chapter 11). This potential rate of production may also be hard to achieve in PNG due to the predicted growth of the already large population.

Overall, however, many PICTs in Group 3 will need to provide access to an additional 20–30 kg of tuna per person per year by 2035 to supply the fish recommended for good nutrition. In PICTs where only relatively small quantities of tuna are harvested within their EEZs (American Samoa, Guam, CNMI), this access will depend heavily on local or imported canned tuna. The quantities of tuna required in Fiji, Solomon Islands and Samoa are smaller but significant nonetheless. Assuming that pond aquaculture fulfills its considerable potential in Fiji (Chapter 11), access will be needed to an additional 5 kg of tuna per person in 2050, and 10 kg in 2100. In Solomon Islands, an additional 5 kg of tuna per person will need to be made available for food security in 2035, increasing to 15 kg in 2050 and 20 kg in 2100. The corresponding quantities for Samoa are 5 kg in 2035, 7 kg in 2050 and 12 kg in 2100.

The good news is that access to tuna for all PICTs in Group 3 is expected to increase in 2035 (**Table 12.7**). Production of pond aquaculture is also expected to be aided by increased temperatures and higher rainfalls in 2035, provided ponds are built where they will not be affected by floods (Chapter 11).

The benefits of climate change for the plans to increase access to fish are expected to continue for most PICTs in Group 3 in 2050 and 2100. PNG and Solomon Islands are the main exceptions – catches of skipjack tuna in their EEZs are projected to fall by ~ 11% and 5% under A2 in 2050, and by ~ 30% and 15% under A2 in 2100, respectively (**Table 12.7**). However, PNG and Solomon Islands are still expected to continue to make relatively large catches of tuna despite the projected decreases. These catches should be sufficient to provide access to the fish needed for food security, and to support substantial industrial fisheries and processing operations (Section 12.9.3.3). Catches of skipjack tuna are also projected to fall slightly in Guam and Nauru under the A2 scenario in 2100 (**Table 12.7**).

12.8 Vulnerability of plans to create additional livelihoods

The plans to increase the number of livelihoods derived from fisheries and aquaculture in the region (Section 12.4.2) are expected to be either progressively enhanced or retarded by climate change, depending on the resource involved (**Table 12.15**).

By 2035, the changing climate is expected to make more skipjack tuna available in both the western and eastern parts of the region (but particularly in the east) (**Table 12.7**), creating more scope for jobs on fishing vessels and in processing plants, provided plans to increase the 'domestication' of these industries (Section 12.2.2) are successful. Opportunities to increase the number of livelihoods based on the capture of nearshore pelagic fish species by coastal fisheries are also expected to increase substantially in the eastern part of the region due to the higher projected abundances of skipjack and yellowfin tuna there (Chapter 8). Although good opportunities for new livelihoods based on the tuna component of nearshore pelagic fish should also exist in the west (Section 2.2.4), they will not be favoured by climate change to the same extent because the nearshore pelagic fishery is dominated by non-tuna species, such as Spanish mackerel, which are more closely associated with coral reefs (Chapter 9).

Other commercial coastal fisheries resources (demersal fish and invertebrates targeted for export) are also expected to decline slightly because of increasing CO_2 emissions by 2035 (Chapter 9), limiting opportunities to create more livelihoods, over and above the gains that could be made from effective management in the interim. The projected degradation of coastal habitats, and increase in sea surface temperatures and ocean acidification, are also expected to affect production from coastal aquaculture by 2035 (Chapter 11). This is not the case for freshwater pond aquaculture, however, which is likely to be boosted throughout much of Melanesia by the projected increases in rainfall and water temperatures. Slight increases in opportunities to earn income from freshwater fisheries in PNG are also expected for the same reasons (Chapter 10).

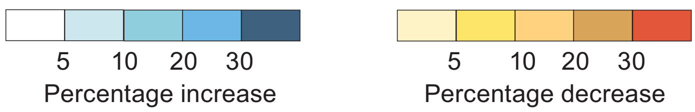
These patterns are likely to be maintained in 2050, except that no increases in the catch of skipjack tuna by industrial fleets, and a decrease in the catch of nearshore pelagic fish by coastal fisheries, may occur in the west (**Table 12.15**). The general patterns described for 2035, and the changing trends for 2050, are expected to strengthen by 2100 (**Table 12.15**), although there is increased uncertainty about the distribution and abundance of skipjack tuna in 2100 (Chapter 8). The exception is in the western part of the region, where catches of skipjack tuna are projected to decrease by > 20% in 2100 (**Table 12.7**), potentially resulting in fewer jobs based on fishing for tuna.

We have not done a formal analysis of the relative vulnerability among PICTs of the plans to optimise the number of livelihoods that could be created from the resources that underpin fisheries and aquaculture in the region. Such an analysis would be difficult given the problems involved in (1) constructing composite indices for exposure and sensitivity across the various oceanic and coastal fisheries and aquaculture resources involved; and (2) weighting the various components of exposure and sensitivity indices due to insufficient data on the jobs based on each resource. Instead, each PICT should be able to ascertain the general direction and magnitude of the likely impact of climate change on their plans to create livelihoods across the sector as a whole from the information in **Table 12.15**.

It is also important to note that the vulnerability of plans to maximise the number of livelihoods that can be derived from fisheries and aquaculture does not depend only on the projected future status of resources. Climate change can affect other aspects of people's lives and livelihoods directly and indirectly, for example, through inundation of coastal land, destruction of coastal infrastructure, or impacts on non-fishing features of coastal livelihood systems, including agriculture. Also, climate change is not the only large-scale driver of change in employment opportunities in fisheries and aquaculture. Other drivers include technological change (e.g. substitution of labour by technology), changing demographics (rural-urban migration, international labour migration), shifts in culture, educational attainment and lifestyle aspirations[7,61,62].

Table 12.15 Summary of the direction of present existing plans (outlined arrows) to derive more livelihoods from the various fisheries and aquaculture resources in the tropical Pacific. The projected effects of the A2 emissions scenario in 2035, 2050 and 2100 on the outcomes of these plans, in terms of percentage increases or decreases, are also shown. ⇧ = increased opportunities, ⇩ = decreased opportunities.

Period	Oceanic fisheries		Coastal fisheries			Freshwater fisheries	Aquaculture	
			Nearshore pelagic fish		Other resources			
	West	East	West	East			Ponds	Coastal
Present	⇧	⇧	⇧	⇧	⇩	⇧	⇧	⇧
2035	↑	↑	No effect	↑	↓	↑	↑	↓
2050	No effect	↑	↓	↑	↓	↑	↑	↓
2100	↓	↑	↓	↑	↓	↑	↑	↓



12.9 Implications

12.9.1 Economic development and government revenue

On balance, the projected changes in catches for the surface tuna fishery from the preliminary modelling – increases in the east and decreases in the west – indicate that there could be more advantages than disadvantages for the region. The possible advantages are that the significant contributions that licence fees already make to government revenue in Kiribati, Tuvalu, Tokelau and Nauru (**Table 12.2**) would be expected to increase as catch rates improve in their EEZs, giving these PICTs the opportunity to negotiate for increased revenue. These projected benefits are expected to endure until 2100 under the A2 emissions scenario for Kiribati, Tuvalu and Tokelau, but only until 2050 for Nauru (**Table 12.9**). More modest benefits to government revenue are also expected for American Samoa, FSM and Marshall Islands until 2050 under the A2 scenario.

Gross domestic product in Marshall Islands is also projected to increase until 2100 as a result of greater catches by their industrial fleet (**Table 12.9**). Similarly, canning operations in American Samoa are expected to benefit from the more eastern distribution of skipjack tuna until 2050 under A2 (**Table 12.9**). Fiji may also have better access to fish for processing in the future.

These benefits will depend on PICTs (1) continuing to develop more flexible management systems to cope with the changing spatial distribution of tuna stocks and fishing effort, and (2) limiting overall catches from the WCPO to recommended levels (Chapter 13).

The potential disadvantages are that the progressive movement of skipjack tuna, and ultimately fishing effort (Section 12.6), further to the east may eventually affect the contribution of fishing and processing operations to GDP, and licence fees to government revenue, for some PICTs in the western part of the region (FSM, Palau, PNG and Solomon Islands). In particular, the plans to expand industrial fishing and processing in PNG and Solomon Islands to domesticate more of the benefits from tuna resources could be affected. To obtain sufficient skipjack and yellowfin tuna to supply processing plants, PNG and Solomon Islands may have to (1) reduce the access of distant water fishing nations to their EEZ to provide more fish for national vessels; (2) require distant water fishing nations operating with their zone to land a proportion of catches for use by local canneries; (3) enhance existing arrangements for their national fleet to fish in other EEZs, and (4) create incentives for tuna caught in other EEZs to be landed in their ports (Chapter 13).

Clearly, the likely effects of climate change on catches of skipjack and yellowfin tuna, and the feasibility of obtaining the fish required in the future, need to be considered when planning the expansion of national fleets, construction of new canneries and loining plants, and development of any additional transshipping ports.

In the event that the four measures described above are not entirely successful in supplying the fish required, or incur costs that affect the profitability of processing operations, production from canneries would be curtailed. Any such effects would also exacerbate problems that canneries in PNG may have in the future if the present import tariff advantages conferred by the IEPA with the EU (Section 12.2.2) are eventually eroded or lost. Overall, however, the effects of any decline in industrial fishing and processing due to climate change on the GDP of PNG and Solomon Islands would be limited because industrial fishing and processing make relatively small contributions to the national economies of these PICTs (**Tables 12.2** and **12.9**).

It is also important to note that the potential opportunities for PICTs in the east arising from altered distributions of tuna due to climate change may be tempered, and the disadvantages for PICTs in the west reinforced, by (1) the prospect that increasing fuel prices will increase the costs of catching and transporting fish, especially for longline fleets[63]; (2) the costs involved in upgrading fleets operating or based in subtropical PICTs to provide acceptable standards of safety at sea[64,65] during more severe storms (Chapter 2); and (3) the projected effects of sea-level rise (Chapter 3), which are eventually expected to result in some wharfs and shore-based facilities having to be rebuilt or relocated, and 'climate proofing' of future infrastructure.

We stress that the possible implications outlined above are based on preliminary modelling of the effects of climate change on tuna stocks. The projected implications will need to be revised regularly as investments are made in models capable of simulations with greater certainty (Chapter 13).

12.9.2 Food security

12.9.2.1 Group 1

There are few implications from the projected effects of climate change on coastal fisheries for the plans to use fish for food security in Cook Islands, Marshall Islands, New Caledonia, Palau, Pitcairn Islands and Tokelau. All these PICTs will continue to have large ratios of coral reef area per person under predicted rates of population growth. Even the greatest projected decrease in production of fish associated with coral reefs under the A2 emissions scenario in 2100 (Chapter 9), is not expected to affect access to the fish needed for food security. In addition, the local abundance of skipjack and yellowfin tuna, which comprise part of the nearshore pelagic fish component of coastal fisheries in these PICTs (Chapter 9), is expected to increase under climate change (**Table 12.7**).

One possible implication is that small-scale commercial fishers supplying urban markets may have to travel greater distances to maintain harvest levels because catch per unit effort of reef-associated fish and invertebrates can be expected to decrease as coral reefs degrade (Chapter 5). A possible increase in ciguatera in PICTs outside the equatorial zone (Chapter 9), and future increases in the cost of fuel[4,7], would compound this situation. To avoid the higher costs of travelling further to fish, or transporting fish greater distances to urban centres, it may be necessary to supplement local reef-based fish production with catches of tuna around anchored inshore FADs. Such investments are expected to be favoured by the re-distribution of tuna due to the changing climate (Chapter 8). However, this intervention is unlikely to be appropriate for communities on the west coast of New Caledonia, where the distances involved in travelling to FADs outside the lagoon may be too great to make small-scale commercial tuna fishing operations economically viable.

12.9.2.2 Group 2

As mentioned in Section 12.7.3, climate change is not expected to significantly affect the potential availability of reef-associated fish per person in many of the PICTs in Group 2. However, Kiribati will need to find other ways to provide the fish needed to meet its traditionally high levels of fish consumption as the combined effects of population growth and climate change reduce the potential availability of fish. Investments in low-cost FADs anchored off Tarawa, and small-scale vessels to fish around them, may be needed to provide the urban population with access to tuna to fill the gap between the fish needed for food security and the fish available from reefs. In the event that such investments are not effective, Kiribati may need to consider negotiating with industrial vessels operating within their EEZ to land a proportion of their tuna catch on a regular basis to supply the local market. Similar considerations are also expected to apply to Papeete in French Polynesia under the A2 scenario in 2100, although there might not be the option to negotiate with industrial vessels unless the greater abundance of tuna in the EEZ leads to development of an industrial fishery (Section 12.9.1).

The combined effects of population growth and climate change can also be expected to have some implications for other PICTs in Group 2, especially Tonga. For the reason described for PICTs in Group 1, the catch per unit effort at locations from where it is cost-effective to send fish to the urban markets is likely to decrease over time, threatening the viability of small-scale fisheries based on reef-associated species. Increased costs for transporting catch to urban markets may prevent small-scale commercial fishing operations at more distant unfished locations. If so, governments will need to provide incentives for supplementing local reef-based fish production with catches from anchored FADs deployed close enough to urban centres to improve access to tuna.

Any risks associated with investing in fishing around low-cost FADs anchored inshore can be expected to reduce over time because skipjack and yellowfin tuna are projected to become more abundant in most PICTs in Group 2 under the B1 and A2 emissions scenarios (**Table 12.7**) (Chapter 8).

12.9.2.3 Group 3

The large shortfalls in the fish required for good nutrition, and the catches of fish likely to be available from reef-associated and freshwater habitats, have several profound implications for PICTs in Group 3. These implications centre around the need to make several rapid and effective decisions to provide access to the fish required for food security in the face of growing populations and climate change. These decisions are (1) improving the management of coastal and freshwater habitats, and fish stocks, to reduce the gap to be filled between the fish needed for food security and the sustainable harvests available from coastal and freshwater resources; (2) assessing how best to fill the gap with available resources (tuna) and potential fish production (pond aquaculture); (3) promoting the 'vehicles' needed to deliver the fish required; and (4) because tuna provides the greatest scope for supplementing the availability of fish for food security, allocating the appropriate proportion of the tuna catch to meet the needs for food security. The rationale for these decisions is explained below.

- **Improving management of natural resources:** Stocks of coastal and freshwater fish and invertebrates, and the habitats they depend on, will need to be managed as well as possible to minimise the gap between the amount of fish needed for good nutrition and the quantity of fish that can be harvested sustainably (**Figure 12.5**). This gap already exists in some PICTs (Section 12.7.4), and increases progressively in all PICTs in Group 3 due to population growth and the projected direct and indirect effects of climate change on stocks (**Table 12.13**). Good management will improve the opportunities for coastal and freshwater fish habitats and stocks to deliver their potential sustainable yields; it will also enable these natural resources to exercise their potential capacity to adapt to climate change (Chapters 5–7, 9 and 10). The key considerations and measures involved in optimising the management of coastal and freshwater habitats, and stocks of fish and invertebrates, are described in Chapter 13.
- **Assessing how best to fill the gap:** With the exception of Guam and Nauru, where either fresh or canned tuna is already required to provide the recommended 35 kg of fish per person per year, coastal fisheries presently have the potential to make substantial contributions to the fish needed for good nutrition (**Figure 12.6**). However, two striking patterns emerge from 2035 onwards:

  1. there is a progressive decline in the relative contribution of coastal fisheries to the fish needed for food security due to the limits on production from coral reefs, mangroves and seagrasses, and the projected direct and indirect effects of climate change on stocks (Chapter 9); and

  2. the progressive increase in the size of the gap to be filled due to population growth means that the great majority of the shortfall in fish required for food security will need to be met using tuna and the bycatch from industrial tuna purse-seine and longlining operations (**Figure 12.6**).

  The role of tuna in providing fish for PICTs in Group 3 in the future is profound – not only does the amount of fish needed increase over time; tuna has to supply an increasing percentage of the total fish required (**Figure 12.6**). It is fortunate indeed that the region has rich tuna resources, and that the preliminary modelling suggests that the most abundant species (skipjack tuna) is likely to be more abundant in the EEZs of many PICTs in Group 3 in the future (**Table 12.7**) (Chapter 8). This potentially important finding needs to be confirmed by more rigorous modelling, and complemented by modelling for yellowfin tuna. In addition, the tuna catch for local consumption should be included in the general tuna management framework of the Western and Central Pacific Fisheries Commission.

Pond aquaculture has potential to make locally important contributions, possibly amounting to ~ 10% of the total fish required nationally by 2100 in some PICTs. It is also fortunate that freshwater pond aquaculture is expected to be favoured by climate change (Chapter 11).

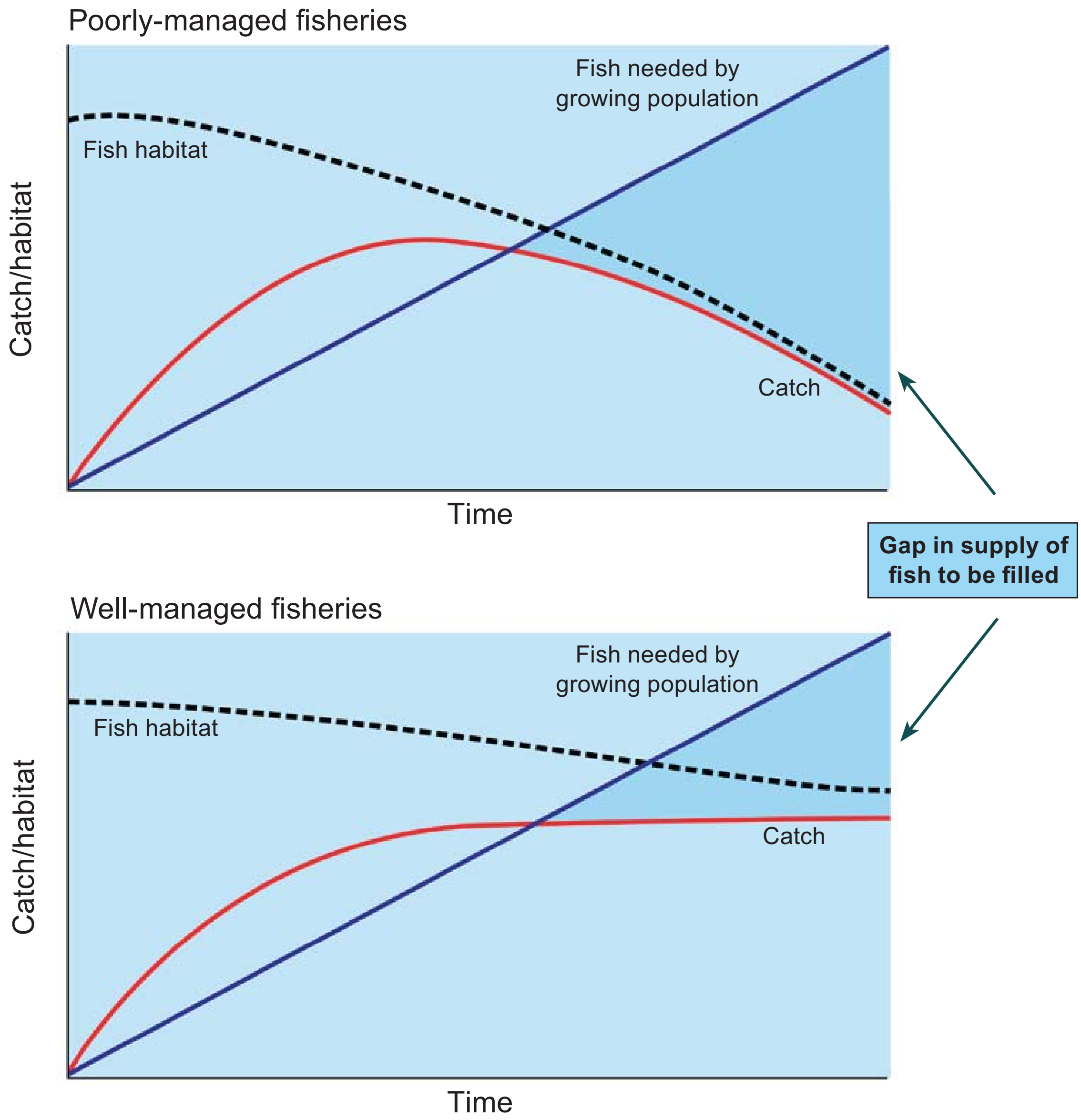
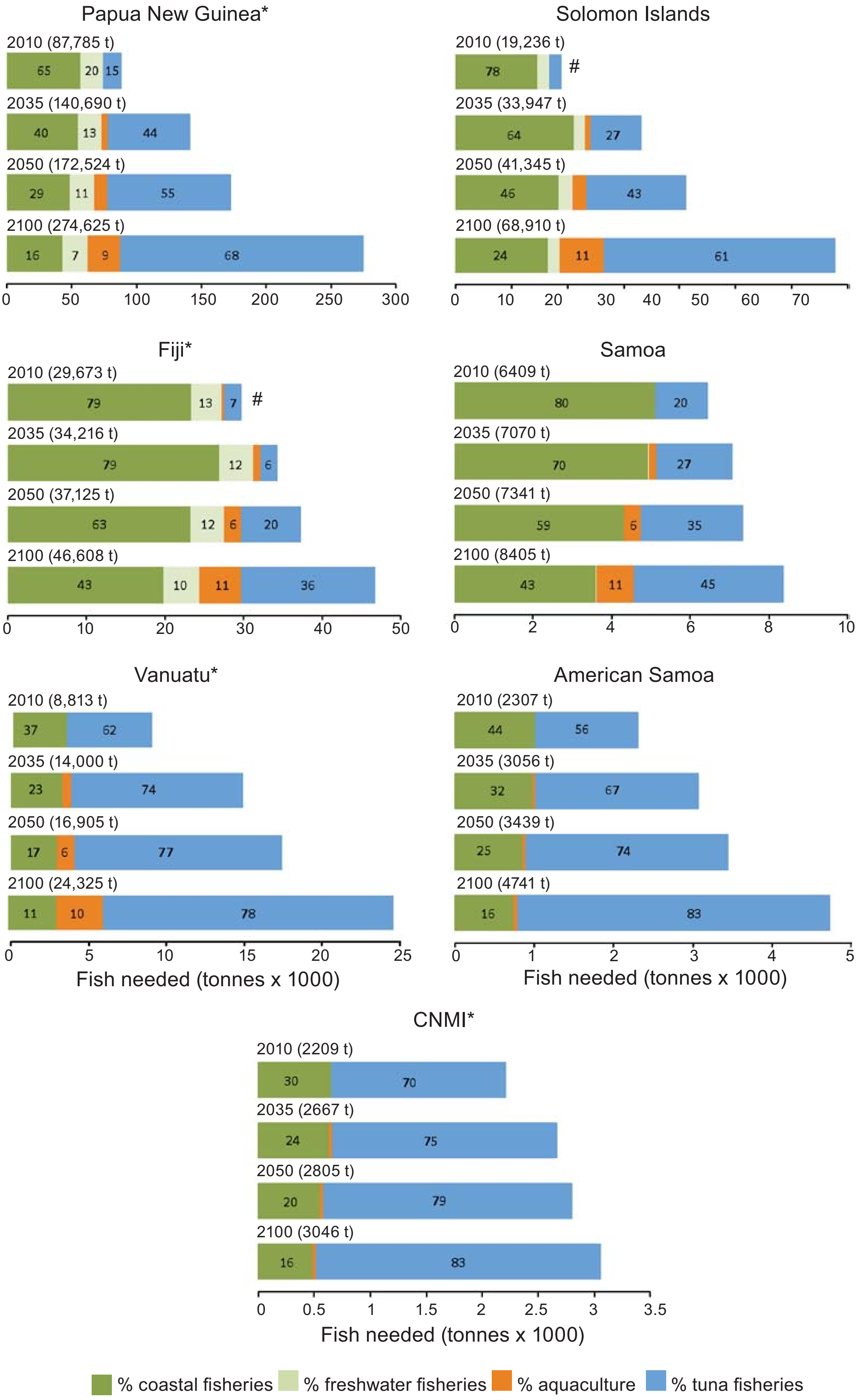


Figure 12.5 The importance of managing coastal and freshwater fish habitats and stocks well to minimise the gap between the fish required by rapidly growing populations in Pacific Island countries and territories in Group 3 for food security, and potential sustainable harvests of fish.



Papua New Guinea*
2010 (87,785 t)
65 20 15
2035 (140,690 t)
40 13 44
2050 (172,524 t)
29 11 55
2100 (274,625 t)
16 7 9 68
0 50 100 150 200 250 300
Solomon Islands
2010 (19,236 t)
78 #
2035 (33,947 t)
64 27
2050 (41,345 t)
46 43
2100 (68,910 t)
24 11 61
0 10 20 30 40 50 60 70
Fiji*
2010 (29,673 t)
79 13 7 #
2035 (34,216 t)
79 12 6
2050 (37,125 t)
63 12 6 20
2100 (46,608 t)
43 10 11 36
0 10 20 30 40 50
Samoa
2010 (6409 t)
80 20
2035 (7070 t)
70 27
2050 (7341 t)
59 6 35
2100 (8405 t)
43 11 45
0 2 4 6 8 10
Vanuatu*
2010 (8,813 t)
37 62
2035 (14,000 t)
23 74
2050 (16,905 t)
17 6 77
2100 (24,325 t)
11 10 78
0 5 10 15 20 25
Fish needed (tonnes x 1000)
American Samoa
2010 (2307 t)
44 56
2035 (3056 t)
32 67
2050 (3439 t)
25 74
2100 (4741 t)
16 83
0 1 2 3 4 5
Fish needed (tonnes x 1000)
CNMI*
2010 (2209 t)
30 70
2035 (2667 t)
24 75
2050 (2805 t)
20 79
2100 (3046 t)
16 83
0 0.5 1 1.5 2 2.5 3 3.5
Fish needed (tonnes x 1000)
% coastal fisheries
% freshwater fisheries
% aquaculture
% tuna fisheries

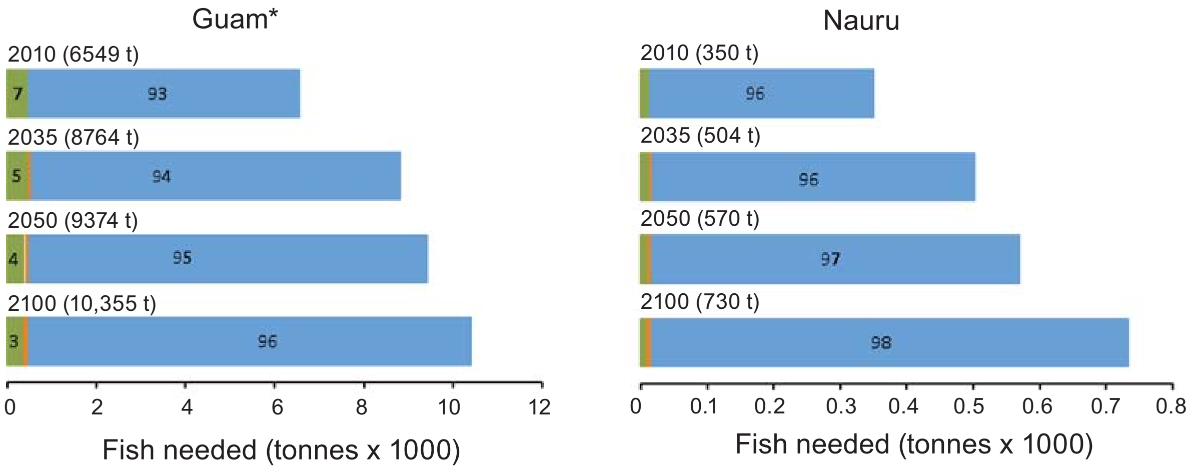


Figure 12.6 Percentage contributions of tuna (■), coastal fisheries (■), freshwater fisheries (■) and aquaculture (■) required to supply 35 kg of fish per person per year for Pacific Island countries and territories (PICTs) in Group 3 in 2010, 2035, 2050 and 2100. Contributions from coastal fisheries are based on estimated sustainable production of 3 tonnes per km^2 of reef per year and have been adjusted for the projected effects of climate change (A2 emissions scenario) on the demersal fish, non-tuna nearshore pelagic fish and subtidal and intertidal invertebrates that comprise coastal fisheries (Appendix 12.2). * indicates PICTs that do not currently have national average fish consumption of ~ 35 kg per person per year; for all other PICTs estimates are limited to supplying 35 kg even though traditional rates of fish consumption may be greater (**Table 12.5**). The fish required for food security in PNG in the future is based on the estimated national average of 13 kg per person per year, rather than 35 kg, to reflect the difficulties of distributing fish to the large inland population. # indicates that coastal fisheries alone have the potential to provide 35 kg of fish per person in 2010 but estimated contributions from tuna and freshwater fisheries are also shown. 'Tuna' also includes bycatch from industrial tuna fishing vessels.

- **Promoting 'vehicles' to fill the gap:** PICTs in Group 3 will need to take active measures to promote the 'vehicles' described in Section 12.7.1 and Chapter 13 for catching and distributing tuna that allow both subsistence fishers in rural areas and urban populations to access this important resource in ways they can afford. Although, not all of the possible vehicles apply to every PICT in Group 3 (**Table 12.16**), many national governments will need to (1) establish networks of inshore FADs for the benefit of coastal communities as part of the national infrastructure for food security, and (2) provide incentives for enterprises in urban areas to store, distribute and sell lower grade (small) tuna and bycatch landed by industrial fleets (Chapter 13).

  To ensure that pond aquaculture can also fulfill its potential to help close the gap for inland communities with difficulty gaining access to tuna, governments will need to reconcile the use of pond aquaculture for food security with any possible effects on freshwater biodiversity[44,66] (Chapter 11), and implement the associated policies described in Chapter 13. The use of fish for food security in inland areas of PNG is expected to remain a problem, however, because pond aquaculture may only ever have the potential to supply 1–4 kg of fish per person per year. Transporting canned tuna produced by the expanding number of fish processing operations in PNG to inland communities is another possible way of increasing access to fish (see below). However, unless the benefits of the lucrative mining and gas industries in PNG flow to inland communities, they are unlikely to have the income to purchase more canned tuna.

Table 12.16 Possible vehicles for providing access to the additional fish needed for food security in Pacific Island countries and territories (PICTs) in Group 3.

PICT	Inshore FADs*	Landed tuna and bycatch	Local canned tuna	Imported canned tuna**	Pond aquaculture
Melanesia					
Fiji	x	Longline	x	x	x[a,e]
PNG	x	Purse-seine	x	x	x[a]
Solomon Islands	x	Purse-seine	x	x	x[b]
Vanuatu	x	Longline		x	x[a]
Micronesia					
Guam	x	Longline		x	x[c]
Nauru	x	No fish landed		x	x[d]
CNMI	x	Longline		x	x[c]
Polynesia					
American Samoa	x	Longline, purse-seine	x	x	x[c]
Samoa	x	Longline		x	x[a]

* FADs = low-cost, anchored fish aggregating devices; ** includes other fish caught and/or canned outside the region, e.g. mackerel; a = pond aquaculture established using tilapia; b = pond aquaculture using tilapia under consideration; c = limited capacity to expand pond aquaculture; d = limited capacity to expand pond aquaculture and milkfish is the preferred species; e = pond aquaculture of milkfish under development.

- **Allocating tuna for food security:** The quantities of tuna required for future food security in PNG and Solomon Islands dwarf the amounts needed by the other PICTs in Group 3 (**Figure 12.6**). Together with Nauru, PNG and Solomon Islands also stand out from the other PICTs in Group 3 as the only countries where recent catches of tuna from their national EEZs (and archipelagic waters) can directly supply the additional fish required for food security (**Table 12.17**).

  An important implication for PNG and Solomon Islands is that, due to the effects of population growth alone, an increasing proportion of annual average tuna catches will need to be allocated over time to provide the quantities of fish their populations need for good nutrition (**Table 12.17**). These proportions reach 22% and 16% for PNG and Solomon Islands, respectively, in 2050, increasing to 43% and 38% in 2100. The projected effects of the A2 emissions scenario on the distribution and abundance of skipjack tuna (**Table 12.7**) indicate that these proportions would increase marginally in 2050, and to ~ 60% for PNG and ~ 45% for Solomon Islands by 2100 (**Table 12.17**).

  Although some of this allocation will need to be given directly to coastal communities to catch tuna around inshore FADs, it is expected to have little effect on the profitability of tuna canneries in PNG and Solomon Islands because (1) the processing facilities already market substantial proportions of their products on the domestic market, and (2) canned tuna is one of the most practical vehicles for making more fish available to rapidly growing populations. Nevertheless, the implications for canneries of the relative benefits of sales to local markets versus export markets, and the costs involved in sourcing additional tuna from outside the EEZ if necessary, require formal economic cost: benefit analyses (Chapter 13).

Addressing the implications outlined in this section should not be deferred – they are urgent national priorities. Most PICTs in Group 3 are already facing major shortfalls in the fish needed for good nutrition of their populations (**Table 12.13**). Therefore, the most appropriate vehicles for filling the gap need to be identified and developed. Because such vehicles take time to establish or scale-up, even Fiji and Solomon Islands should embark on implementing them now.

Although low-cost FADs anchored in inshore waters to improve access to tuna for subsistence fishers are a large part of the solution, there is also a need to encourage small-scale commercial fishing operations around these FADs, and to develop fisheries for the smaller pelagic species. Catches made by commercial fishers not only help provide access to fish for households not engaged in harvesting, the income derived also improves food security[46].

Table 12.17 Average total tuna catch (2005–2009) taken in the EEZs of Papua New Guinea (PNG), Solomon Islands and Nauru, and the amount that would need to be allocated to provide the fish recommended for good nutrition of their populations in 2035, 2050 and 2100. Allocations are described as the percentages of average annual total tuna catch based on population growth alone (Popn) (**Table 12.7**), and on the reduced projected catch due to the effects of the A2 emissions scenario.

PICT	Average total tuna catch (tonnes)	Tuna needed for food								
		2035			2050			2100		
		Tonnes	% catch (Popn)	% catch (A2)	Tonnes	% catch (Popn)	% catch (A2)	Tonnes	% catch (Popn)	% catch (A2)
PNG	436,357	62,059	14	14	94,786	22	24	186,996	43	61
Solomon Islands	111,796	9289	8	8	17,919	16	17	42,286	38	45
Nauru	58,792	477	1	1	526	1	1	637	1	1

12.9.3 Livelihoods

The implications of the projected changes in production of oceanic, coastal and freshwater fisheries, and aquaculture, for plans to create additional sustainable livelihoods from these resources are that (1) more flexible arrangements may need to be made to ensure that tuna can be supplied cost-effectively to the existing and proposed canneries and loining enterprises in the region; and (2) livelihoods may need to be switched from one resource to another.

To ensure that the tuna processing plants in PNG and Solomon Islands obtain sufficient fish at reasonable prices as skipjack and yellowfin tuna move further east, the national governments may need to implement the measures outlined in Section 12.9.1. These measures include allocating more of the tuna within their EEZs to national fleets, negotiating access for their vessels to fish more regularly in other zones, and providing incentives for fish caught in the EEZs of neighbouring countries to be delivered to their canneries. Such measures may need to be introduced sooner rather than later if competition for canning tuna, driven by a potential global excess in processing capacity[67], limits the supply of fish to national canneries. A full Economic Partnership Agreement (EPA) with the EU should be of great assistance to PNG in this regard because it channels fish from the region destined for EU markets through PNG. Solomon Islands would also benefit from an IEPA and full EPA with the EU. The tuna canneries in Fiji, PNG and Solomon Islands provide regionally significant numbers of jobs (**Table 12.6**) and any reductions in their capacity can be expected to have substantial effects on many households in towns such as Levuka, Madang, Lae and Noro[68].

Within the coastal fisheries sector, the effort of small-scale fishers will need to be increasingly transferred from demersal fish associated with coral reefs, mangroves and seagrasses to nearshore pelagic species, particularly skipjack and yellowfin tuna. A practical way of doing this will be to invest in networks of anchored, inshore FADs, as described inSection 12.9.2. Transferring effort to nearshore pelagic species is not only expected to maintain the livelihoods of fishers as the projected declines in coastal fisheries occur (Chapter 9), it should create additional job opportunities in several PICTs because of the likely increases in the abundance of tuna (**Table 12.7**).

For aquaculture, much of the potential for growth in jobs is expected to be based on farming freshwater fish in ponds. Such enterprises are likely to be enhanced by the projected increases in rainfall and temperature. However, governments may need to provide incentives for the private sector to invest in the hatcheries and other infrastructure required to capitalise on these opportunities.

12.10 Conclusions

On balance, the Pacific Island countries and territories appear to be in a better position than nations in other regions to cope with the implications of climate change for fisheries and aquaculture. Although the changes in distribution and abundance of tuna projected from preliminary modelling are likely to require more flexible approaches for supplying existing and proposed canneries, and may eventually reduce GDP and/or government revenues slightly for a few countries in the western Pacific, the expected effects for the region as a whole are among the better possible outcomes. In particular, PICTs with the greatest dependence on tuna (e.g. Kiribati, Nauru, Tuvalu and Tokelau) are likely to receive greater benefits as the fish move east, whereas the projected decreases in production occur in those PICTs where industrial fishing and processing make only modest contributions to GDP and government revenue due to the relatively large size of their economies. The implications would have been much more severe if there was a redistribution of tuna from east to the west.

The rich tuna resources of the region also promise to provide PICTs in Groups 2 and 3 with options to deliver access to the fish recommended for good nutrition (except for populations in inland PNG) as the projected production of coastal fisheries declines due to the direct and indirect effects of climate change (Chapter 9). Even in countries like PNG and Solomon Islands, where abundances of tuna are projected to decline progessively, there should still be ample tuna to use for national food security – it is a matter of allocating the required proportion of average tuna catches for this purpose.

The increased rainfall expected to occur throughout the tropical Pacific in the future also provides several PICTs with the opportunity to increase access to fish through development of pond aquaculture. This is likely to be most important for the inland populations in Fiji, PNG and Solomon Islands, and for the rapidly growing urban populations in these countries. Higher future rainfall and water temperatures are also expected to improve the production of freshwater fisheries in Melanesia.

The various adaptations and policies needed to harness the opportunities for greater contributions from fisheries and aquaculture to economic development, food security and livelihoods expected to result from the changing climate, and the measures needed to reduce the threats, are described in detail in Chapter 13.

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Appendix 12.1 Indices used to assess the adaptive capacity of Pacific Island countries and territories

PICT	Adaptive capacity (AC)*										
	Health			Education			Governance index[c]	Size of economy		AC index Economic development[d]	AC index Food security[e]
	Infant mortality	Life expectancy	Index[a]	Literacy 15–24 years	Primary school enrolment	Index[b]		GDP per person	Index		
Melanesia											
Fiji	0.76	0.48	0.57	0.99	0.94	0.97	0.32	3175	0.09	0.49	0.35
New Caledonia	0.98	0.92	0.94	0.99	0.99	0.99	0.43	29,898	1.00	0.84	0.89
PNG	0.03	0	0.1	0.62	0.77	0.67	0.26	991	0.01	0.26	0.18
Solomon Islands	0.00	0.29	0.2	0.85	0.94	0.88	0.33	753	0.00	0.35	0.24
Vanuatu	0.67	0.56	0.6	0.87	0.93	0.89	0.59	2127	0.05	0.53	0.37
Micronesia											
FSM	0.47	0.54	0.52	0.95	1.00	0.97	0.56	2183	0.05	0.52	0.37
Guam	0.89	1	0.96	0.95	1.00	0.97	0.72	22,661	0.75	0.85	0.82
Kiribati	0.23	0.29	0.27	0.97	0.97	0.97	0.55	653	0	0.45	0.30
Marshall Islands	0.47	0.57	0.54	0.98	0.90	0.95	0.51	2851	0.08	0.52	0.37
Nauru	0.33	0.72	0.59	0.99	0.60	0.86	0.56	2807	0.07	0.52	0.37
CNMI	0.96	0.89	0.91	0.95	1.00	0.97	0.59	12,638	0.41	0.72	0.62
Palau	0.75	0.64	0.68	0.99	0.93	0.97	0.59	8423	0.27	0.63	0.51
Polynesia											
American Samoa	0.89	0.77	0.81	nea	nea	nea	0.76	6995	0.22	0.45	0.37
Cook Islands	0.83	0.71	0.75	0.99	1.00	0.99	0.38	8553	0.27	0.60	0.49
French Polynesia	0.97	0.88	0.91	0.99	0.99	0.99	0.43	22,427	0.74	0.77	0.76
Niue	0.95	0.92	0.93	0.99	1.00	0.99	0.38	5828	0.18	0.62	0.47
Samoa	0.73	0.8	0.78	0.99	0.90	0.96	0.63	2872	0.08	0.61	0.43
Tokelau	0.46	0.63	0.58	0.99	1.00	0.99	0.75	1000	0.01	0.58	0.39
Tonga	0.77	0.68	0.71	0.99	0.95	0.98	0.41	2319	0.06	0.54	0.38
Tuvalu	0.51	0.4	0.44	0.99	1.00	0.99	0.58	1831	0.04	0.51	0.36
Wallis and Futuna	1.00	0.86	0.90	0.99	0.99	0.99	0.43	14,552	0.47	0.70	0.44

* All indices have been standardised and normalised – see text for explanation of how the indices were derived; a = 1/3 infant mortality rate and 2/3 life expectancy; b = 2/3 literacy and 1/3 primary school enrolment; c = estimates made based on the index for a PICT with similar political and cultural circumstances where a governance index was not provided by Kaufman et al. (2008)[56], e.g. the indices for French Polynesia and Wallis and Futuna have been based on the index for New Caledonia; d = average of indices for health, education, governance and size of the economy; e = based on weighted average, where size of the economy is weighted 0.5 and the indices for health, education and governance by 0.167. No indices are available for Pitcairn Islands; nea = no estimate available.

Appendix 12.2 Method for estimating changes in abundance of fish for food security due to climate change

Because most of the fish[xxii] eaten in Pacific Island countries and territories (PICTs) comes traditionally from easily accessible coastal habitats, this analysis has been limited to the effects of projected changes to the three components of coastal fisheries associated with coral reefs and other coastal habitats used for food security in the region: demersal fish (DF), nearshore pelagic fish (NSP), and shallow subtidal and intertidal invertebrates (SII) (Chapter 9). Projected changes in freshwater fisheries production (Chapter 10) have also been considered in the case of communities for some PICTs.

To estimate changes in the productivity of fish available per person from each of the three components of coastal fisheries for each PICT in 2035, 2050 and 2100 under the B1 and/or A2 emissions scenarios, we assumed that the present-day, combined sustainable harvests of DF, NSP and SII are equivalent to the median estimate for production of fish associated with coral reefs, i.e. 3 tonnes per km^2 of coral reef per year[21] (Chapter 9). In making this assumption, it is implicit that the areas of coral reef (Chapter 5) used to produce the estimates also include lagoons with seagrasses and intertidal flats (Chapter 6). The assessments also assume that there will be no change in the incidence of ciguatera fish poisoning, which effectively reduces the coastal fisheries production available for food security (Chapter 9).

Estimates of total available fish per person for each PICT in 2035, 2050 and 2100 under the B1 and/or A2 scenarios were, therefore, calculated as the area of coral reef multiplied by 3 tonnes of fisheries production per km^2 of reef per year divided by the predicted population. These estimates were then partitioned to identify the proportion contributed by DF, NSP and SII, based on the estimated proportions of DF, NSP and SII making up coastal fisheries in each PICT (Chapter 9). However, because a proportion of NSP in each PICT is derived from tuna species, which have little dependence on coastal habitats (see below), the relative contributions of DF, the non-tuna component of NSP and SII to the estimates of 3 tonnes of fish per km^2 of reef per year had to be recalculated. This was done as outlined in the hypothetical example below, where 50% of NSP is comprised of tuna.

Percentage of coastal fishery

DF	SII	NSP	Tonnes
50%	10%	40%	10,000

Percentage of coastal fishery showing contribution of tuna

DF	SII	NSP non-tuna	NSP tuna	Tonnes
50%	10%	20%	20%	10,000

Adjusted percentage of coastal fisheries associated with coral reefs

DF	SII	NSP non-tuna	Tonnes
62.5%	12.5%	25%	8000

xxii Used in the broad sense to include fish and invertebrates.

To estimate the effects of population growth alone on the availability of fish per person in the future, relative to the recommended 35 kg per person per year[3], estimated sustainable production (reef area x 3 tonnes per km^2 per year) was divided by the predicted population.

To estimate the effects of the projected decreases in the DF, non-tuna NSP and SII available per person for the B1 and/or A2 emissions scenarios in 2035, 2050 and 2100, the proportions of DF, non-tuna NSP and SII contributions to annual availability of coastal fisheries production per person were adjusted by the percentages derived from Chapter 9, and summarised in the table below. The projected increases in production of freshwater fish under all scenarios (Chapter 10) are also shown. Estimates were based on the midpoint of the ranges given in the table below.

Scenario	Component of coastal fisheries				Freshwater fisheries
	DF	NSP non-tuna		SII	
		West**	East***		
B1/A2 2035	-2 to -5%	-4%	-3%	0%	+2.5%
B1 2100*	-20%	-10 to -15%	-4%	-5%	+2.5 to +7.5%
A2 2100	-20 to -50%	-10 to -25%	-8%	-10%	+2.5 to +12.5%

* Approximates A2 2050; ** 15°N–20°S and 130°–170°E; *** 15°N–15°S and 170°E–150°W.

We also explored the availability of fish per person per year at production levels of 1 and 5 tonnes per km^2 per year to consider situations where production may be naturally higher, or higher due to good management, and naturally lower, or lower due to poor management[21] (Chapter 9).

Estimates of fish likely to be readily available for food security in future take into account (a) effects of population growth alone, and (b) additional effects of climate change. An example of these outputs for a hypothetical country is given below.

(a) Change in fish available per person per year in 2100 due to population growth.

Production (tonnes per km^2 per year)	Reef area (km^2)	Popn in 2010	Total fish per person in 2010 (kg)	Popn in 2100	DF (kg)	NSP non-tuna (kg)	SII (kg)	Total fish per person in 2100 (kg)
1	2000	100,000	20	150,000	8	3	2	13
3	2000	100,000	60	150,000	25	10	5	40
5	2000	100,000	100	150,000	42	17	8	67

(b) Change in fish available per person per year in 2100 due to population growth and the effects of the B1 emissions scenario in 2100.

Production (tonnes per km² per year)	Reef area (km²)	Popn in 2010	Total fish per person in 2010 (kg)	Popn in 2100	DF[a] (kg)	NSP non-tuna[b] (kg)	SII[c] (kg)	Total fish per person in 2100 (kg)
1	2000	100,000	20	150,000	7	3	2	12
3	2000	100,000	60	150,000	20	9	5	34
5	2000	100,000	100	150,000	33	15	8	56

a = DF x -20%; b = NSP non-tuna x -10%; c = SII x -5%.

Tuna have not been included in the calculations because although they have been estimated to make up between 25% and 75% of NSP, depending on the PICT (Chapter 9), tuna depend mainly on the food web of the open ocean (Chapters 4 and 8). Thus, tuna are not generally considered to be supported by coastal habitats. In addition, it is not possible to estimate the likely changes in availability of tuna per person in the future because there are few data available to indicate potential present-day sustainable catches of tuna by coastal communities. Given the scale of catches made by the industrial fishery (Section 12.2), however, it is very likely that coastal communities could make substantial catches of tuna if they are provided with access and appropriate fishing methods. Tuna represent a 'safety net' for future supplies of fish in the tropical Pacific (Section 12.9.2.3).

Appendix 12.3 Predicted populations for Pacific Island countries and territories in 2050 and 2100

PICT	Predicted population (in thousands)					Data used to make predictions for 2100				
						Annual growth rate (period)		Rate of change of growth rate	Annual growth rate	Average annual growth rate
						2011–2015	2045–2050	2011–2015 to 2045–2050	2095–2100	2050–2100
	2011*	2015*	2045*	2050*	2100	$r_{2011–2015}$	$r_{2045–2050}$	R	$r_{2095–2100}$	$r_{2050–2100}$
Melanesia	**8797**	**9498**	**15,400**	**16,339**	**25,492**	**1.9**	**1.2**	**-1.4**		**0.9**
Fiji	852	868	1036	1061	1,332	0.5	0.5	-0.1	0.4	0.5
New Caledonia	252	266	338	343	372	1.3	0.3	-4.3	0.0	0.2
PNG	6888	7477	12,467	13,271	21,125	2.0	1.2	-1.4	0.6	0.9
Solomon Islands	553	610	1101	1181	1,969	2.4	1.4	-1.6	0.6	1.0
Vanuatu	252	278	457	483	695	2.4	1.1	-2.3	0.4	0.7
Micronesia	**546**	**579**	**707**	**720**	**808**	**1.4**	**0.4**	**-4.0**		**0.2**
FSM	102	101	108	109	109	-0.4	0.1	-	-	-
Guam	192	212	263	268	296	2.5	0.4	-5.5	0.0	0.2
Kiribati	103	110	157	163	211	1.8	0.8	-2.4	0.2	0.5
Marshall Islands	55	57	62	61	61	0.9	-0.2	-	-	-
Nauru	10	11	16	16	21	1.9	0.8	-2.6	0.2	0.5
CNMI	64	67	79	80	87	1.2	0.3	-4.1	0.0	0.2
Palau	21	21	23	22	22	0.6	-0.1	-	-	-
Polynesia	**668**	**687**	**811**	**826**	**952**	**0.7**	**0.4**	**-1.8**		**0.3**
American Samoa	67	70	94	98	135	1.2	0.8	-1.2	0.5	0.6
Cook Islands	16	16	16	16	16	0.3	-0.2	-	-	-
French Polynesia	272	284	344	349	379	1.1	0.3	-3.8	0.0	0.2
Niue	1	1	1	1	1	-2.1	0.2	-	-	-
Samoa	184	185	207	210	240	0.2	0.3	0.5	0.4	0.3
Tokelau	1	1	1	1	1	-0.2	0.0	-	-	-
Tonga	104	105	120	123	147	0.3	0.4	1.2	0.8	0.4
Tuvalu	11	11	13	14	19	0.5	0.6	0.5	0.8	0.6
Wallis and Futuna	13	13	13	14	14	-0.2	0.1	-	-	-
Total	**10,013**	**10,765**	**16,969**	**17,948**	**27,475**	**1.8**	**1.1**	**-1.4**	**0.6**	**0.9**

* Predictions made using cohort component method (source: Population data sheet, Statistics for Development Programme, SPC, www.spc.int/sdp/);
** see Appendix 12.4 for method used to make predictions for 2100. Predictions for Pitcairn Islands are not included.

Appendix 12.4 Method for predicting population size for Pacific Island countries and territories in 2100

1. Establish projected population growth rates of the period 2011–2015 ($r_{2011–2015}$) and 2045–2050 ($r_{2045–2050}$), based on projection using cohort component method[53].

$$r_{2011–2015} = \ln (Popn_{2015} / Popn_{2011}) / t$$
$$r_{2045–2050} = \ln (Popn_{2050} / Popn_{2045}) / t$$

Where:

ln	=	natural logarithmic function
$Popn_{2010}$	=	projected population size in 2011
$Popn_{2015}$	=	projected population size in 2015
$Popn_{2045}$	=	projected population size in 2045
$Popn_{2050}$	=	projected population size in 2050
t	=	time interval of population estimates (in years)

2. Calculate the average annual rate of change (R) of the population growth rate of the period 2011–2050.

$$R = \ln (r_{2045–2050} / r_{2011–2015}) / t$$

Where:

ln	=	natural logarithmic function
$r_{2010–2015}$	=	population growth rate of the period 2011–2015
$r_{2045–2050}$	=	population growth rate of the period 2045–2050
t	=	time interval between $r_{2011–2015}$ and $r_{2045–2050}$ (34.5 years)

3. Apply the calculated rate of change to the 2045–2050 population growth rate in order to obtain the growth rate of the period 2095–2100 ($r_{2095–2100}$).

$$r_{2095–2100} = \mathrm{Exp} (R \times t) \times (r_{2045–2050})$$

Where:

Exp	=	exponential function
R	=	average annual rate of change of the population growth rate between period 2011–2015 and 2045–2050 (see step 2)
t	=	number of years to project (50 years)
$r_{2045–2050}$	=	population growth rate of the period 2045–2050

4. Average the growth rates of the period 2045–2050 and 2095–2100 to obtain the average annual growth rate of the period 2050–2100 ($r_{2050-2100}$).

$$r_{2050-2100} = (r_{2045-2050} + r_{2095-2100}) \ / \ 2$$

5. Use the average annual growth rate of the period 2050–2100 to calculate the population size in 2100 ($Popn_{2100}$) by applying the formula:

$$Popn_{2100} = Exp\ (r_{2050-2100} \text{ x } t) \text{ x } Popn_{2050}$$

Where:

Exp	=	exponential function
$r_{2050-2100}$	=	estimated average annual population growth rate of the period 2050–2100
t	=	number of years of projection (50 years)
$Popn_{2050}$	=	projected population size in 2050

Exceptions

For countries with an estimated population growth rate of zero or near zero during the period 2045–2050, it is assumed that their population size in 2100 is the same as in 2050. These countries and territories are Cook Islands, Federated States of Micronesia, Marshall Islands, Niue, Palau, Tokelau and Wallis and Futuna.

For countries such as Samoa, Tonga and Tuvalu, it is assumed that the estimated population growth rate during the period 2050–2100 is the same as the average of the period 2011–2050.

Appendix 12.5 Gap in availability of fish for Group 3

Gap between the recommended fish consumption of 35 kg per person per year, and the estimated annual supply of fish per person from coastal (reef-associated) and freshwater fisheries in 2010, 2035, 2050 and 2100 for each of the Pacific Island countries and territories (PICTs) in Group 3. Note that these projected gaps do not incorporate the impacts of climate change and are based on sustainable fisheries production of 3 tonnes per km^2 of coral reef per year.

PICT	Reef area (km^2)*	Coastal fish production per year (tonnes)	Freshwater fish production (tonnes)**	Total fish production (tonnes)	Population (x 1000)***				Total fish available per person per year (kg)				Gap in fish needed for good nutrition per person per year (kg)			
					2010	2035	2050	2100	2010	2035	2050	2100	2010	2035	2050	2100
Melanesia																
Fiji	10,000	30,000	4146	34,146	848	978	1061	1332	40	35	32	26	+(5)	0	3	9
PNG	22,000	66,000	17,500	83,500	6753	10,822	13,271	21,125	12	8	6	4	23	27	29	31
Solomon Islands	8535	25,605	2000	27,605	550	970	1181	1969	50	28	23	14	+(15)	7	12	21
Vanuatu	1244	3732	80	3812	245	400	483	695	16	10	8	6	19	25	27	29
Micronesia																
Guam	238	714	3	717	187	250	268	296	4	3	3	2	31	32	32	33
Nauru	7	21	0	21	10	14	16	21	2	1	1	1	33	34	34	34
CNMI	250	750	0	750	63	76	80	87	12	10	9	9	23	25	26	26
Polynesia																
American Samoa	368	1104	1	1105	66	87	98	135	17	13	11	8	18	22	24	27
Samoa****	2000	6000	10	6100	183	202	210	240	33	30	29	25	2	5	6	10

* Derived from Chapter 5; ** based on estimates by Gillett (2009)[4]; *** source: SPC Statistics for Development Programme; **** based on total reef area to a depth of 100 m; + indicates that there is no gap.